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Rao Vemuri et al.

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(54) **LATERAL REINFORCEMENT SYSTEM AND METHOD FOR CONCRETE STRUCTURES**

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E04B 1/41 (2006.01)
E04C 5/16 (2006.01)

(52) **U.S. Cl.**
CPC ***E04B 1/4178*** (2013.01); ***E04B 1/4185*** (2013.01); ***E04C 5/167*** (2013.01)

(58) **Field of Classification Search**
CPC E04B 1/4178; E04B 1/4185; E04C 5/163; E04C 5/167
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,141,937	A *	11/2000	Dressler	E04C 5/163 52/298
6,240,688	B1 *	6/2001	Dressler	E04C 5/163 52/295
6,655,105	B2 *	12/2003	Swenson	E04C 5/163 403/391
2011/0247291	A1 *	10/2011	Hammon	E04C 5/166 52/684
2013/0186030	A1 *	7/2013	Hebert, Jr.	E04F 21/00 52/698

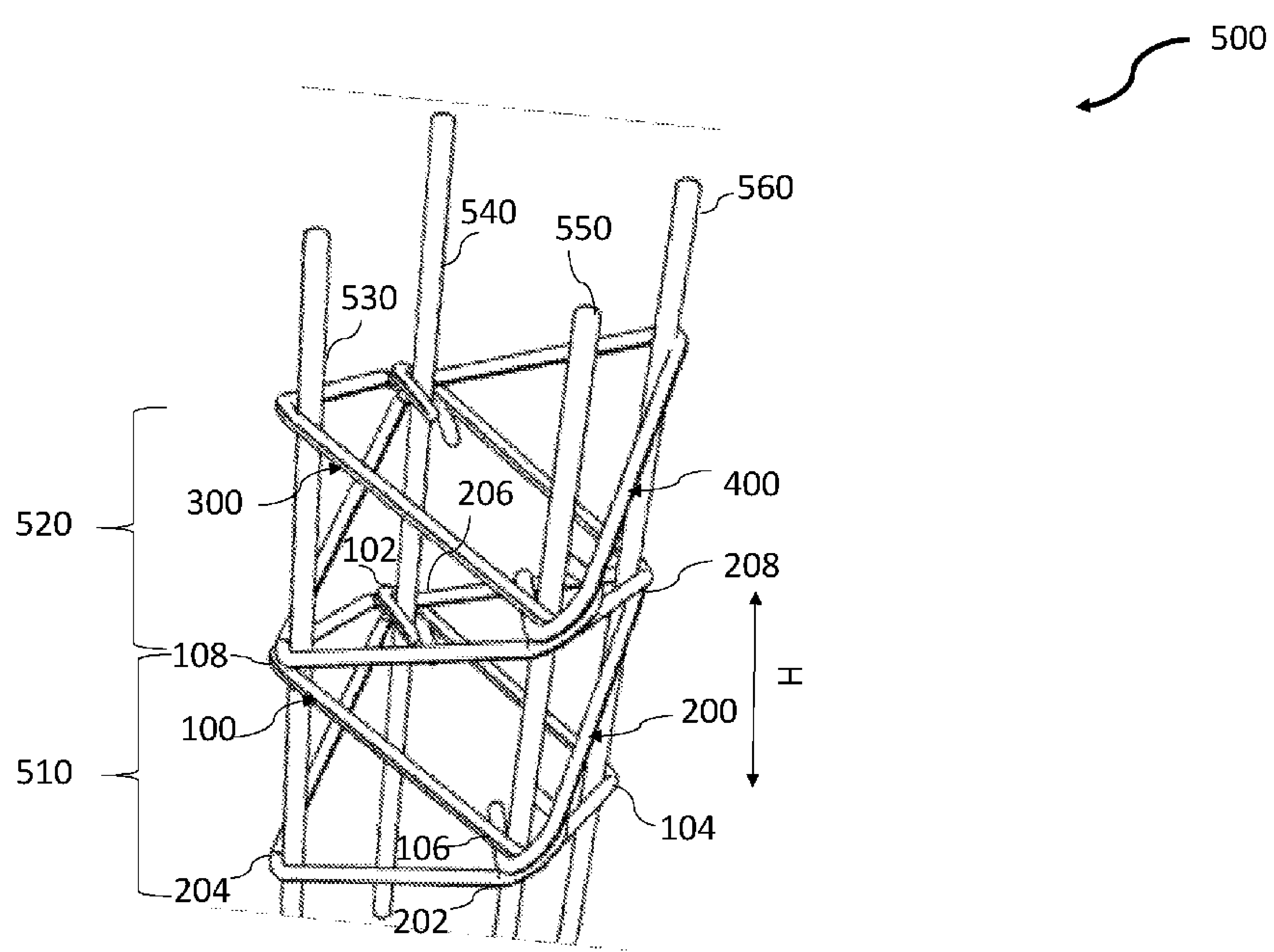
* cited by examiner

Primary Examiner — Andrew J Triggs

(57) **ABSTRACT**

A lateral reinforcement system for a concrete structure having axially disposed structural bars. The lateral reinforcement system comprises a plurality of reinforcement ties disposed at an inclination to the axially disposed structural bars. A pair of reinforcement ties of the plurality of reinforcement ties is disposed at mirror inclinations to each other. In the pair of reinforcement ties, the reinforcement ties cross each other at diametrically opposite corners of the reinforcement ties at diametrically opposite axially disposed structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from inside of the first reinforcement tie at the diametrically opposite structural bar. The plurality of reinforcement ties forms a three-dimensional interwoven network around the axially disposed structural bars.

9 Claims, 28 Drawing Sheets



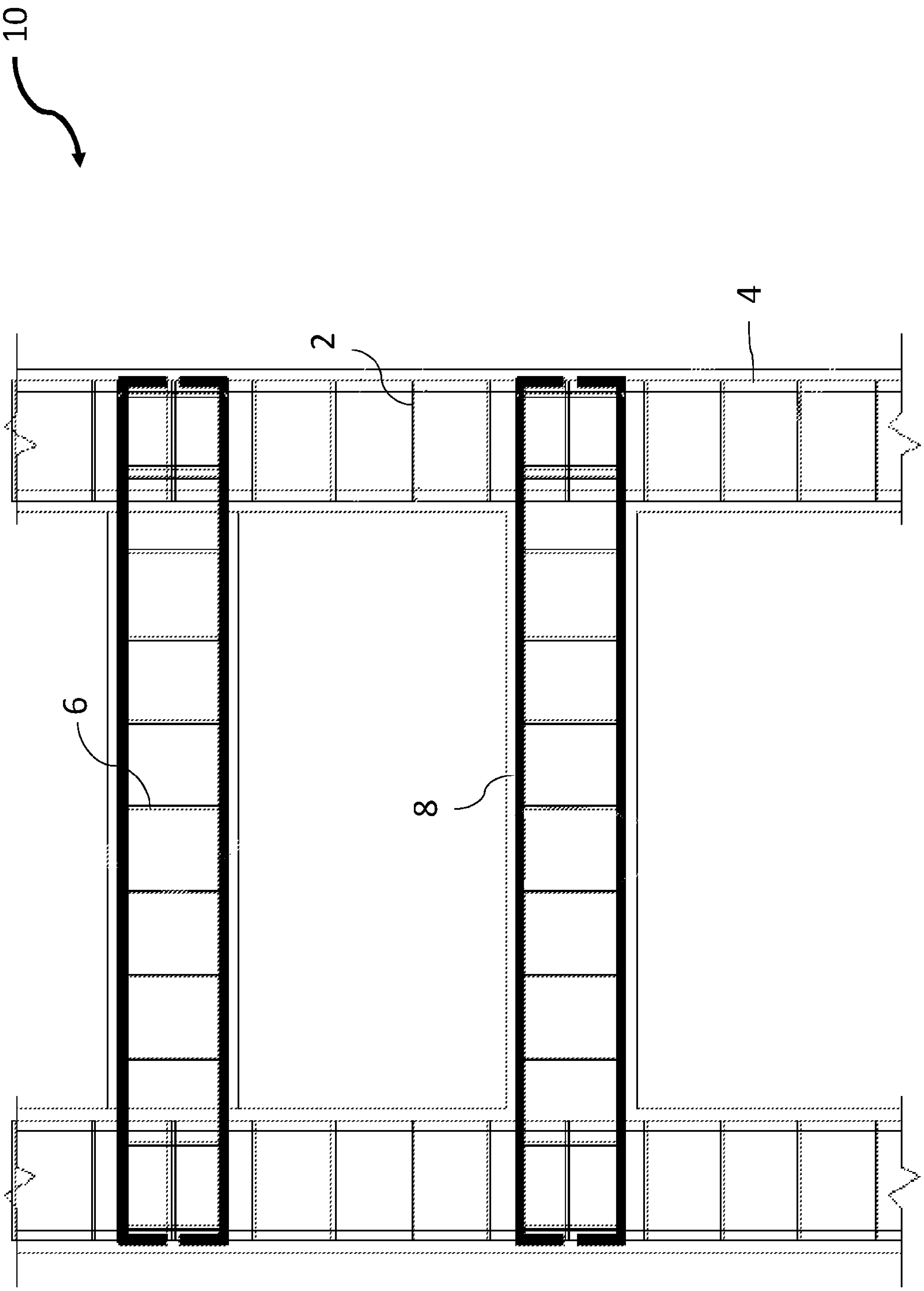


FIG.1 (PRIOR ART)

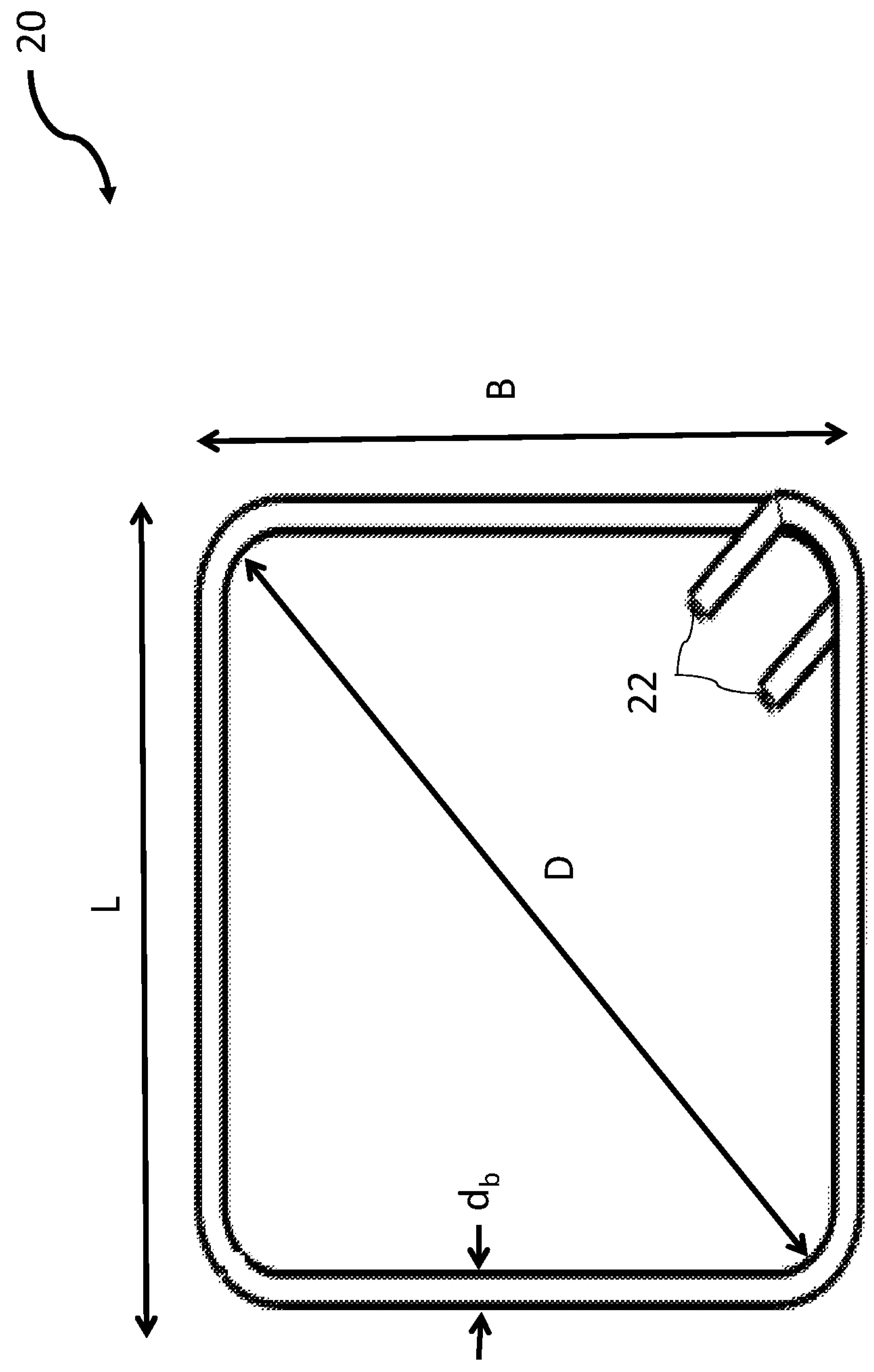


FIG.2 (PRIOR ART)

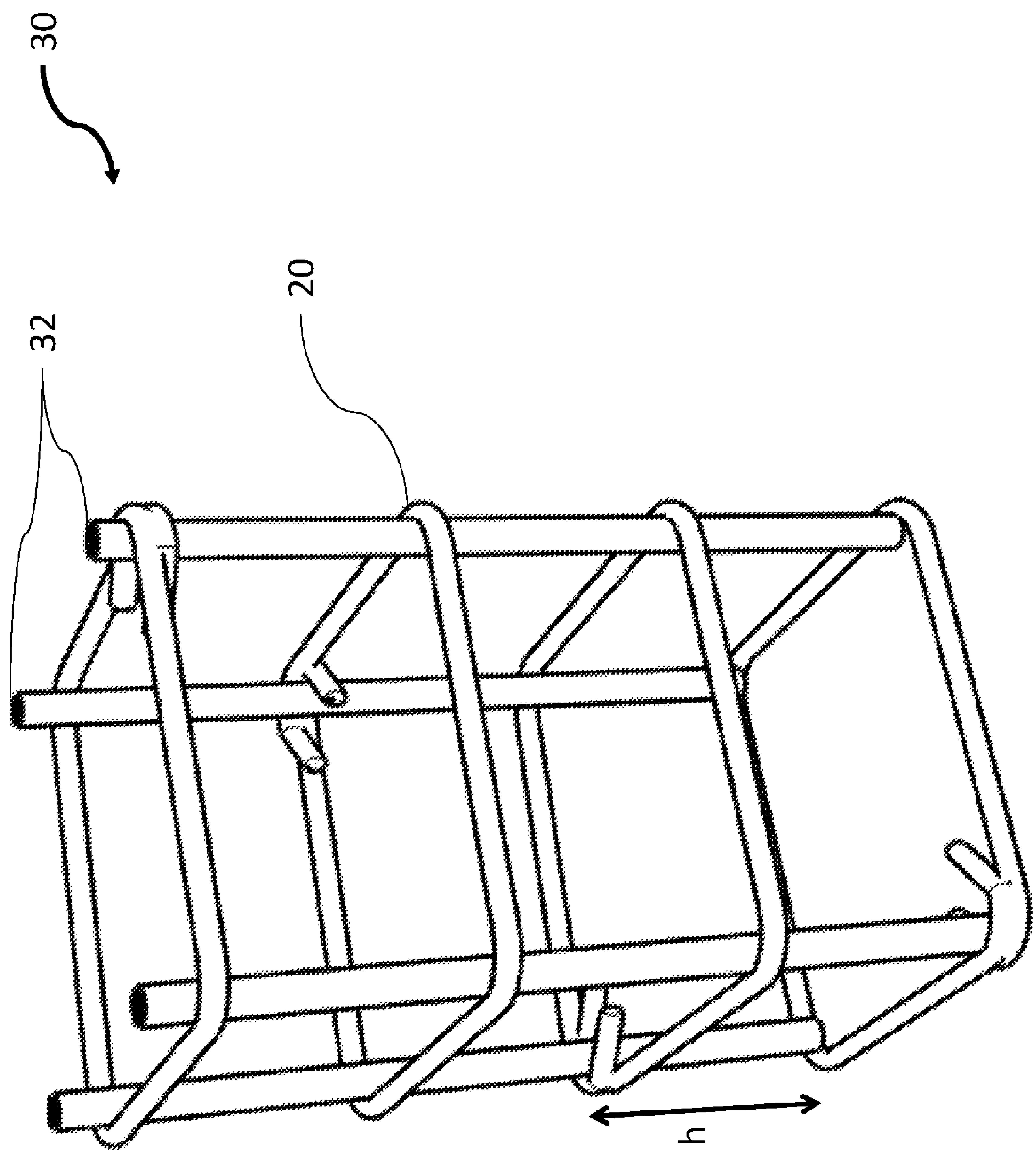


FIG.3 (PRIOR ART)

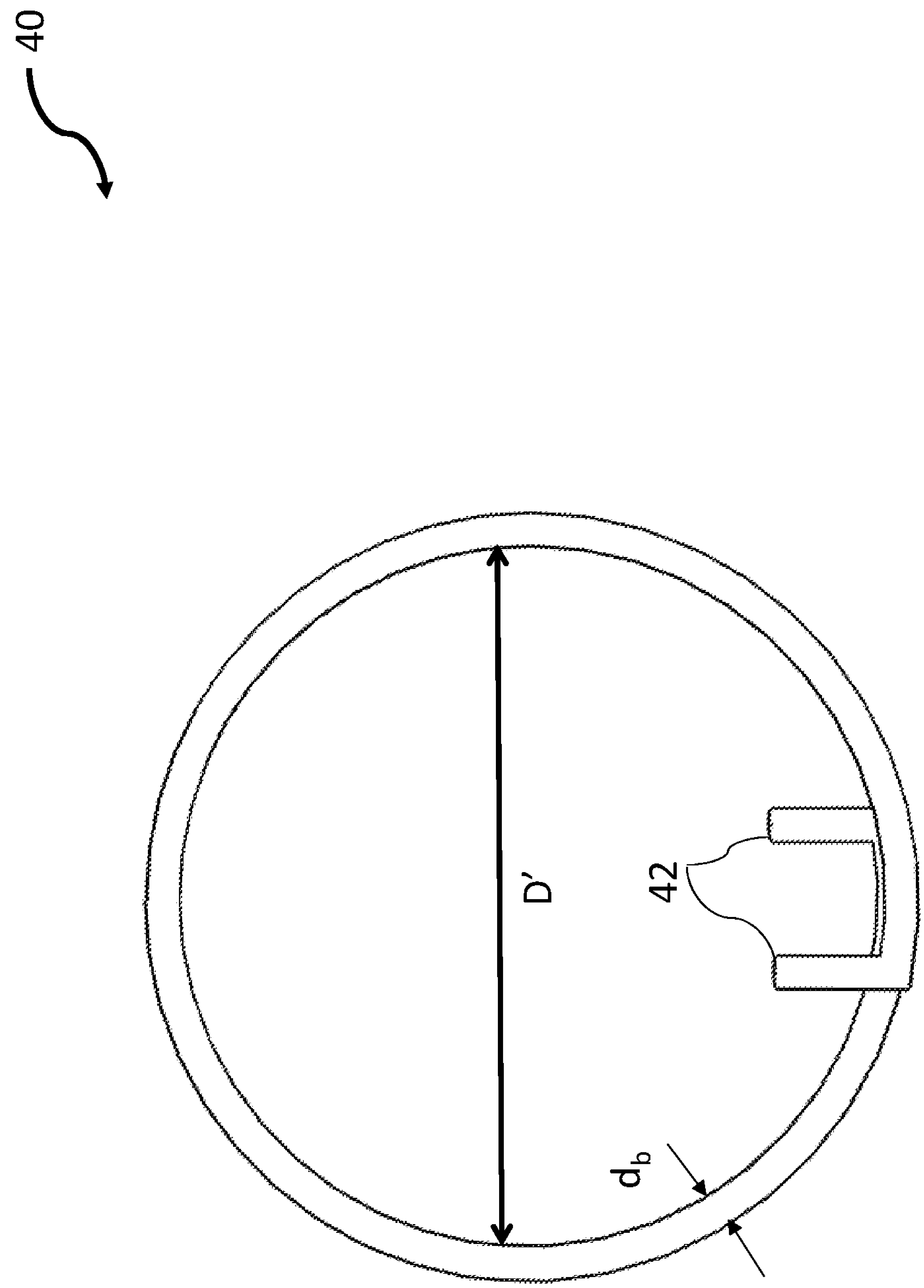


FIG.4 (PRIOR ART)

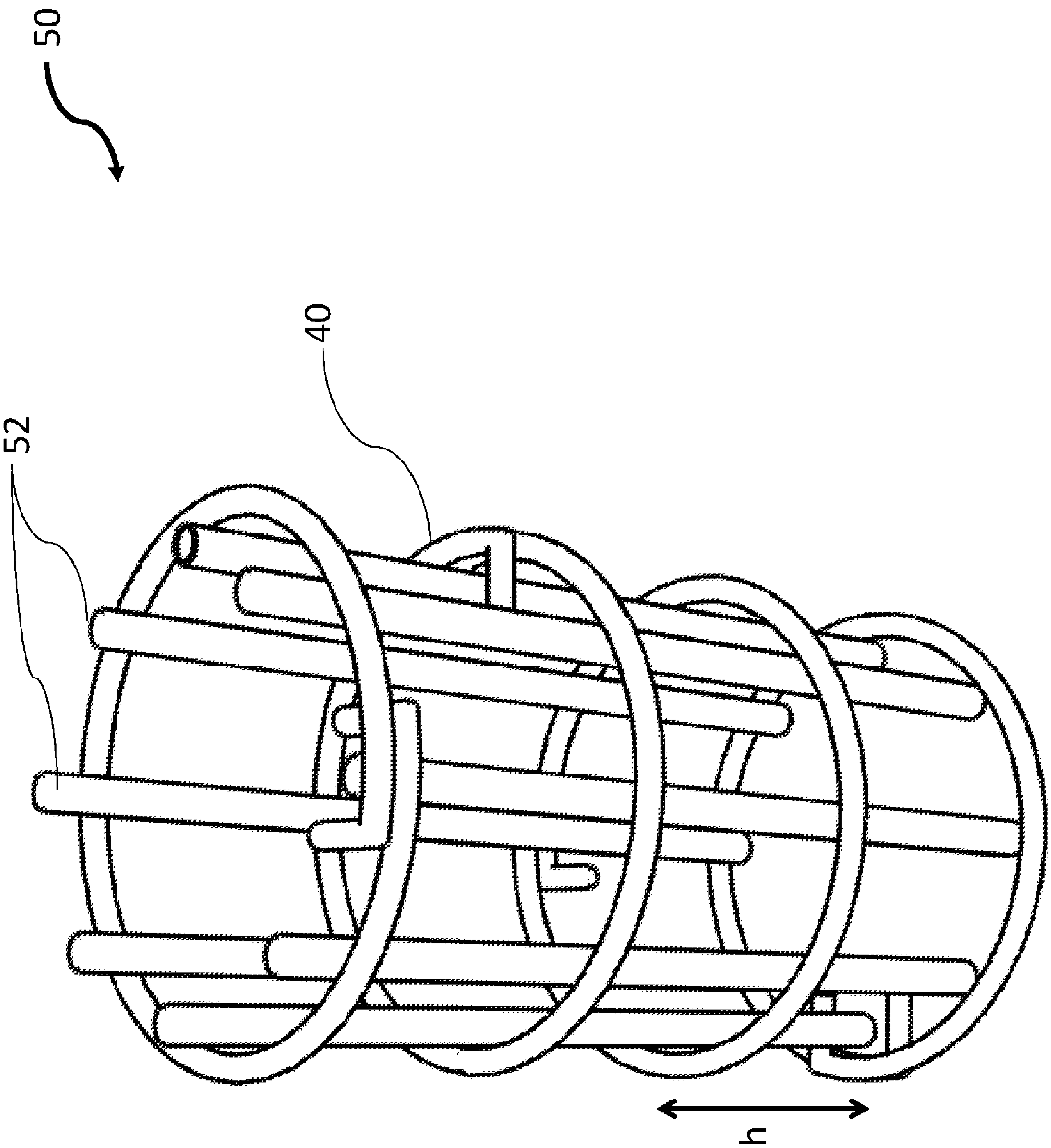


FIG.5 (PRIOR ART)

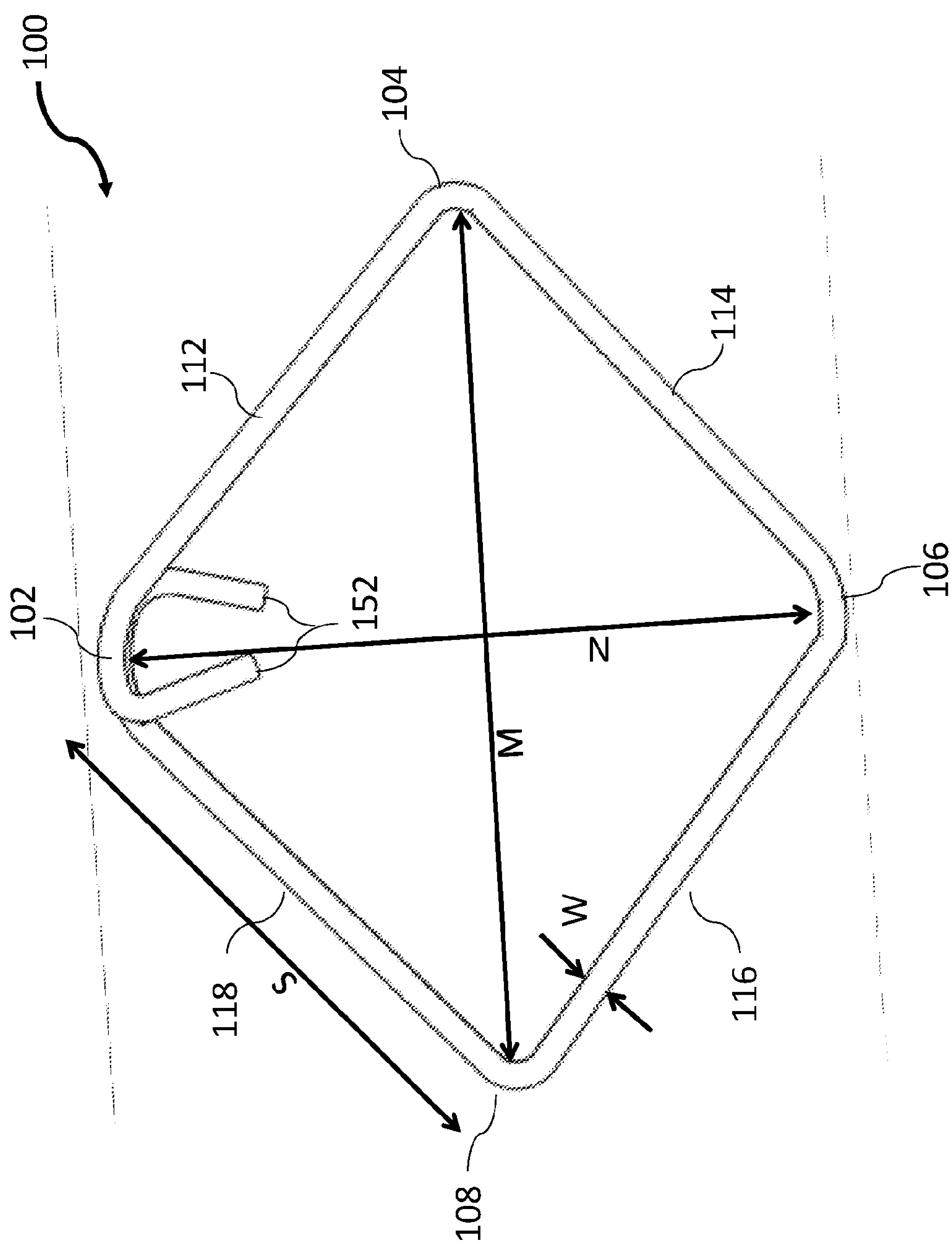
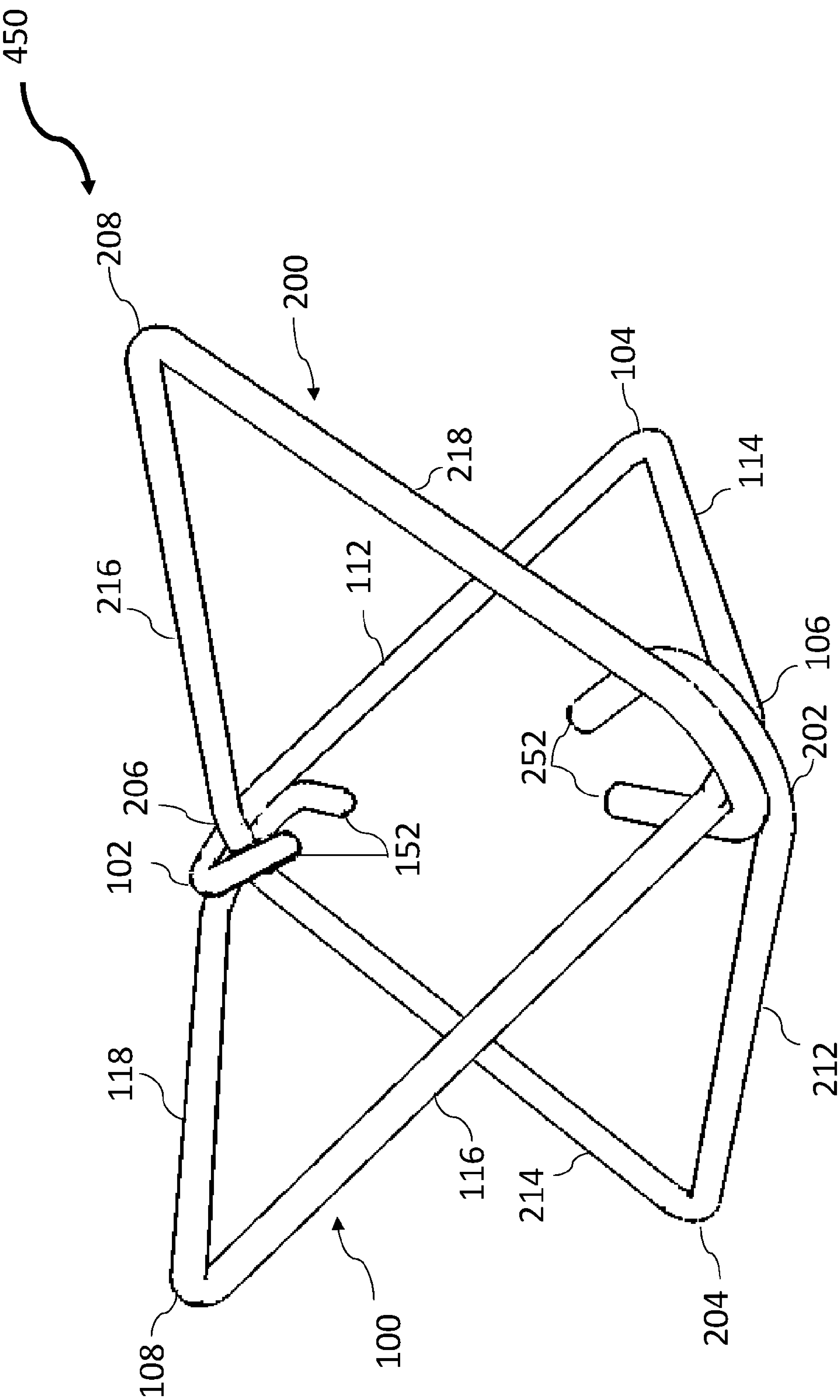


FIG.6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208
200
104
218
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106
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152
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212
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214
204
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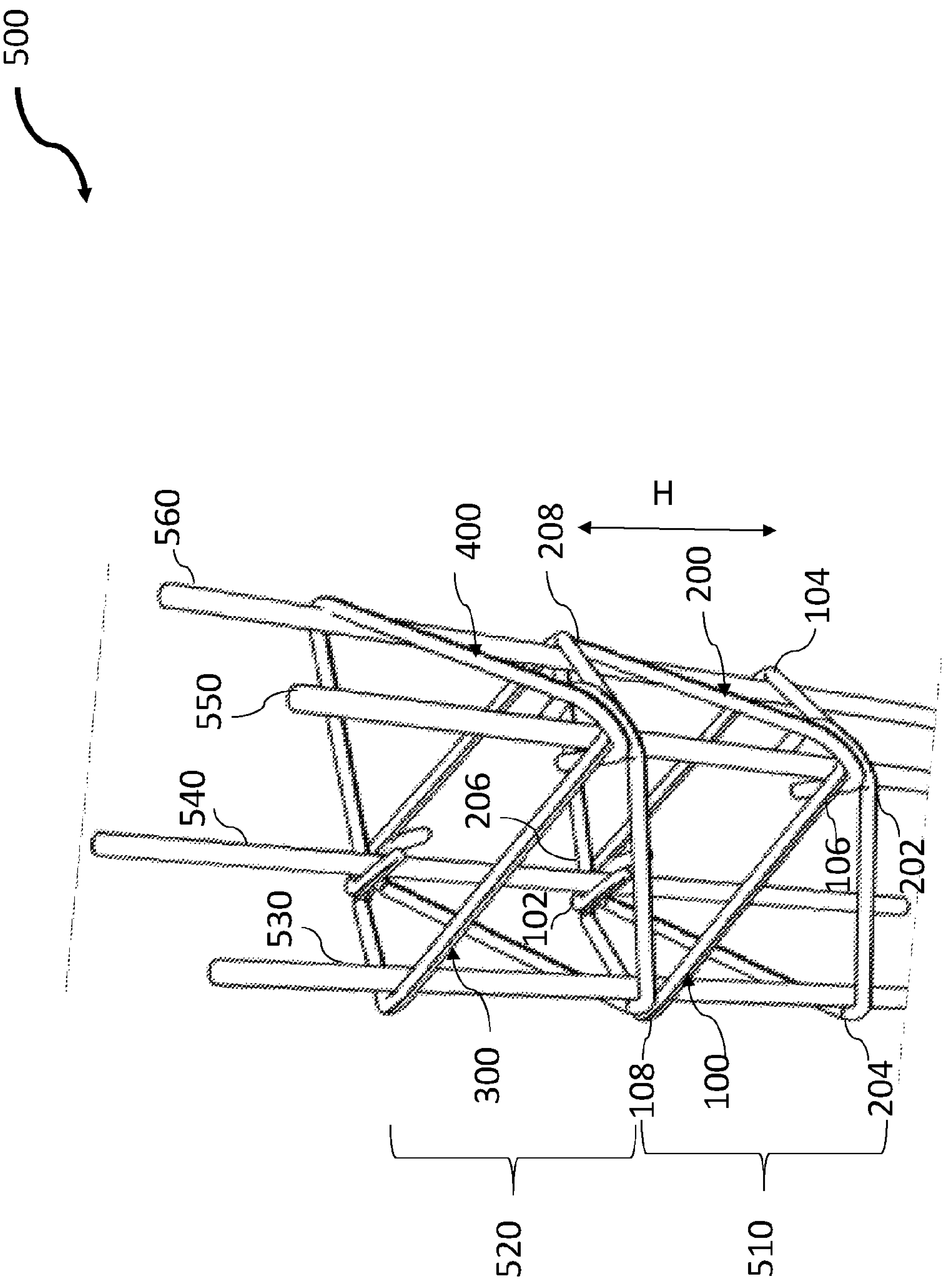
100

FIG.7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H
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550
540
206
106
202
530
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300
108
100
204
520
510

FIG.8

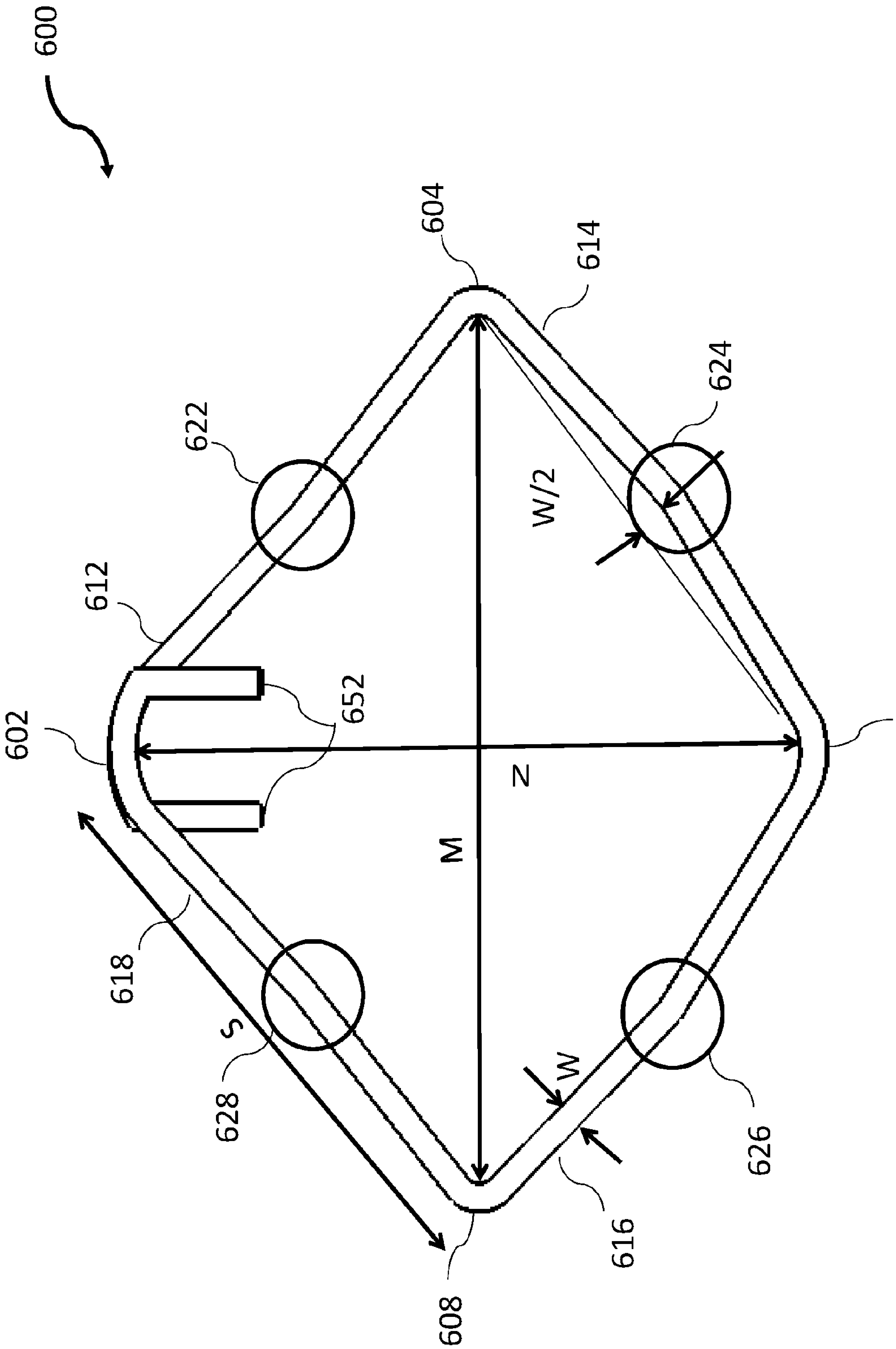


FIG.9A

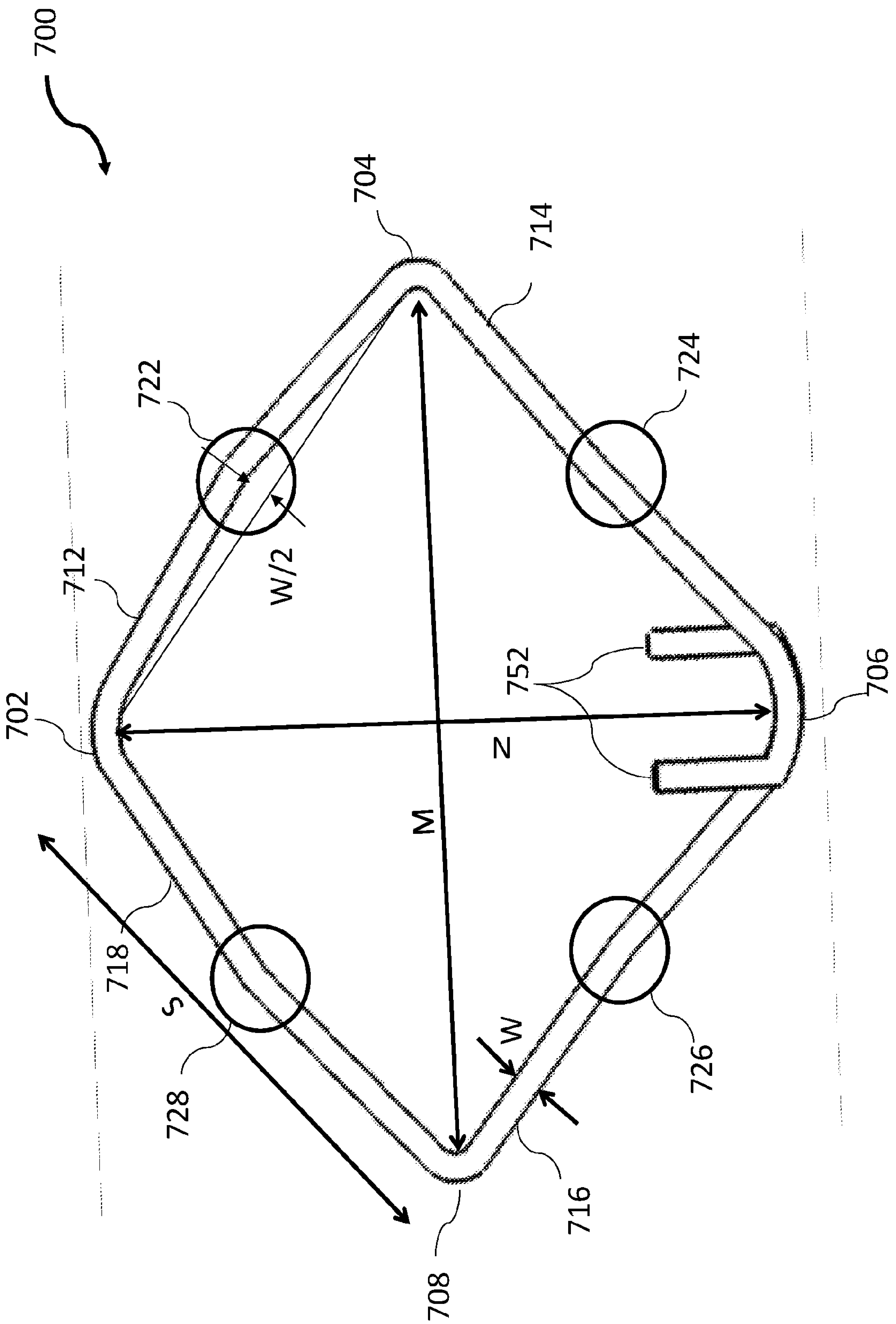


FIG.9B

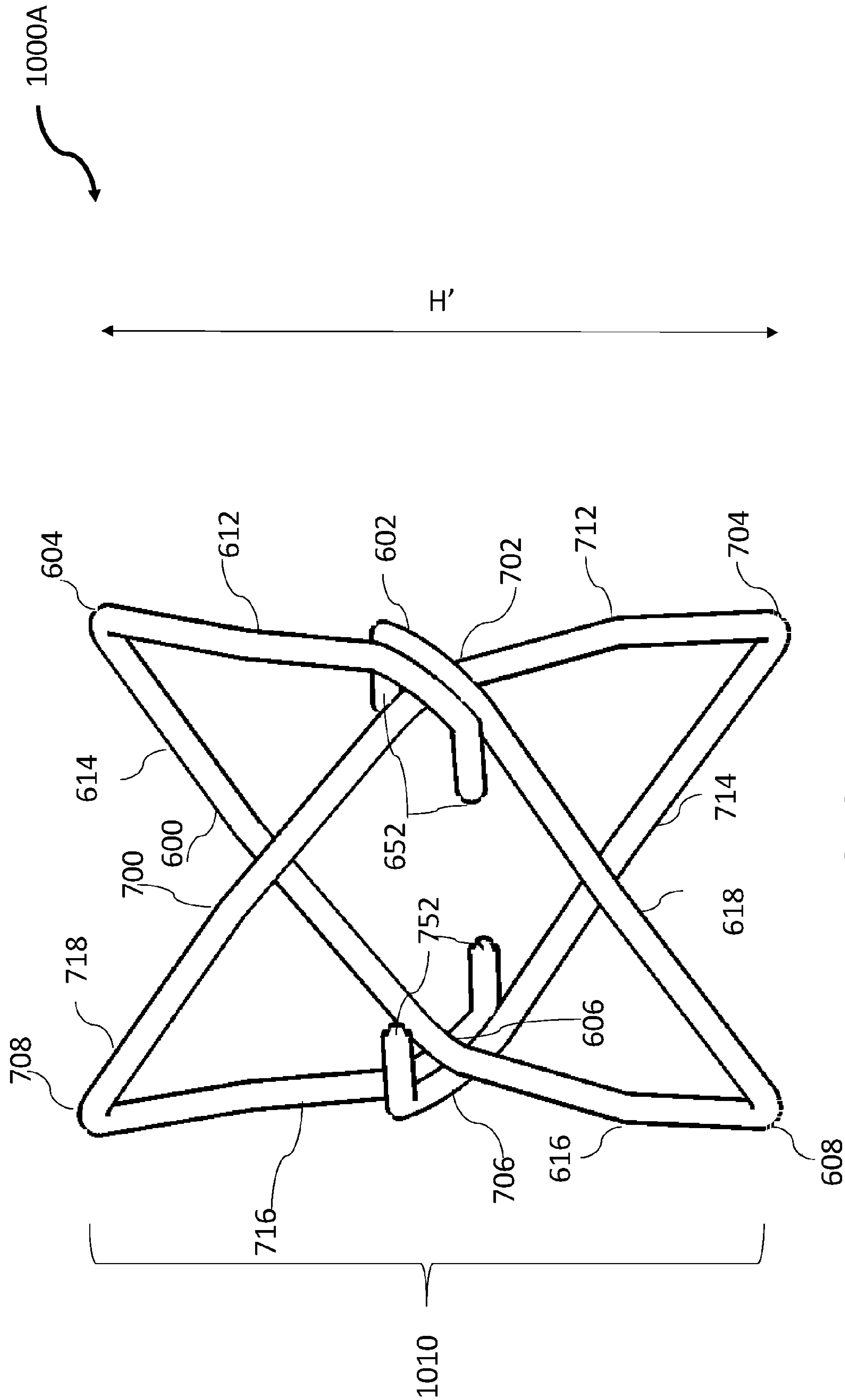

1000A
H'
604
612
602
702
712
704
614
600
700
652
714
618
752
718
606
708
716
706
616
608
1010

FIG.10A

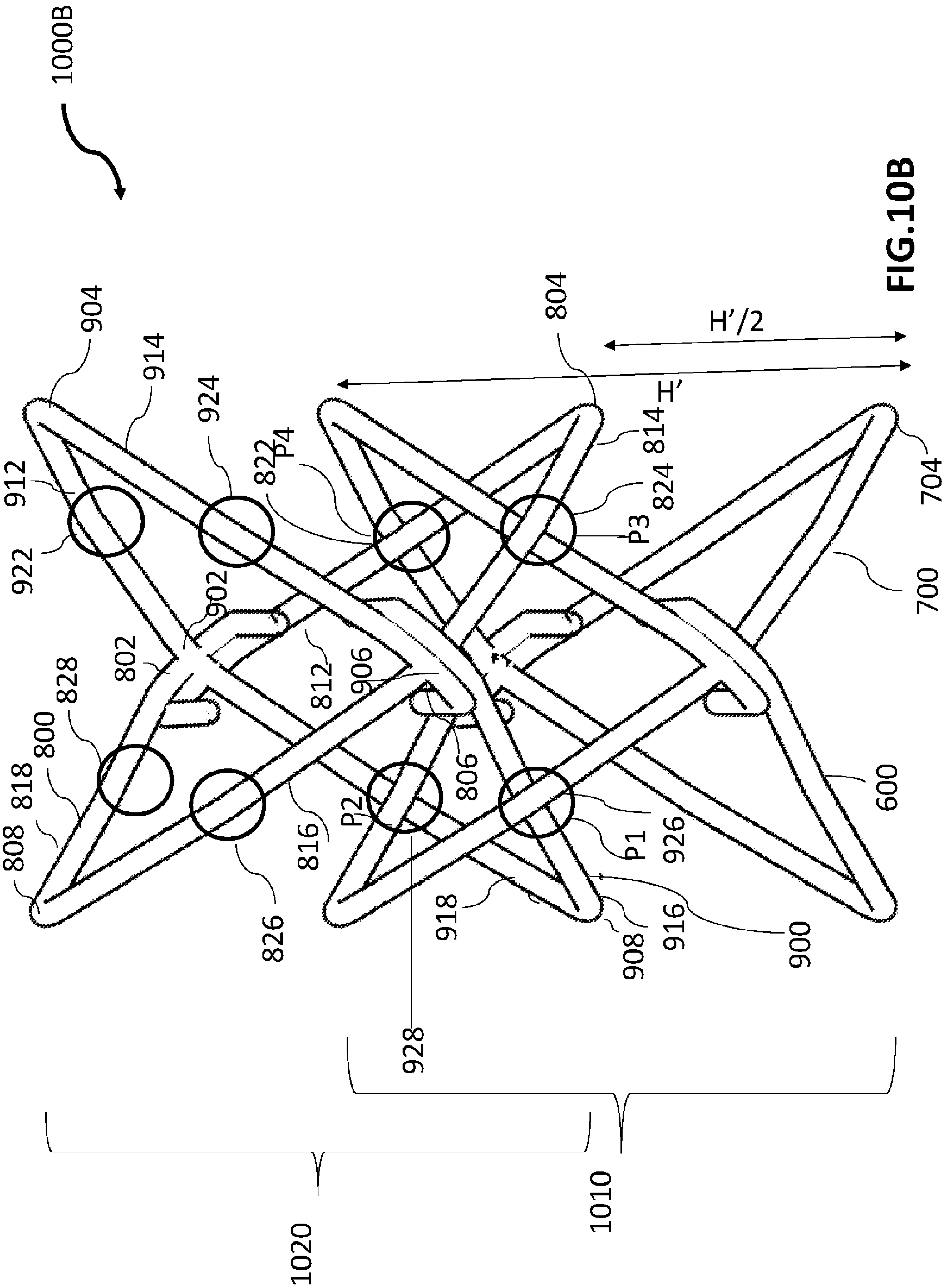
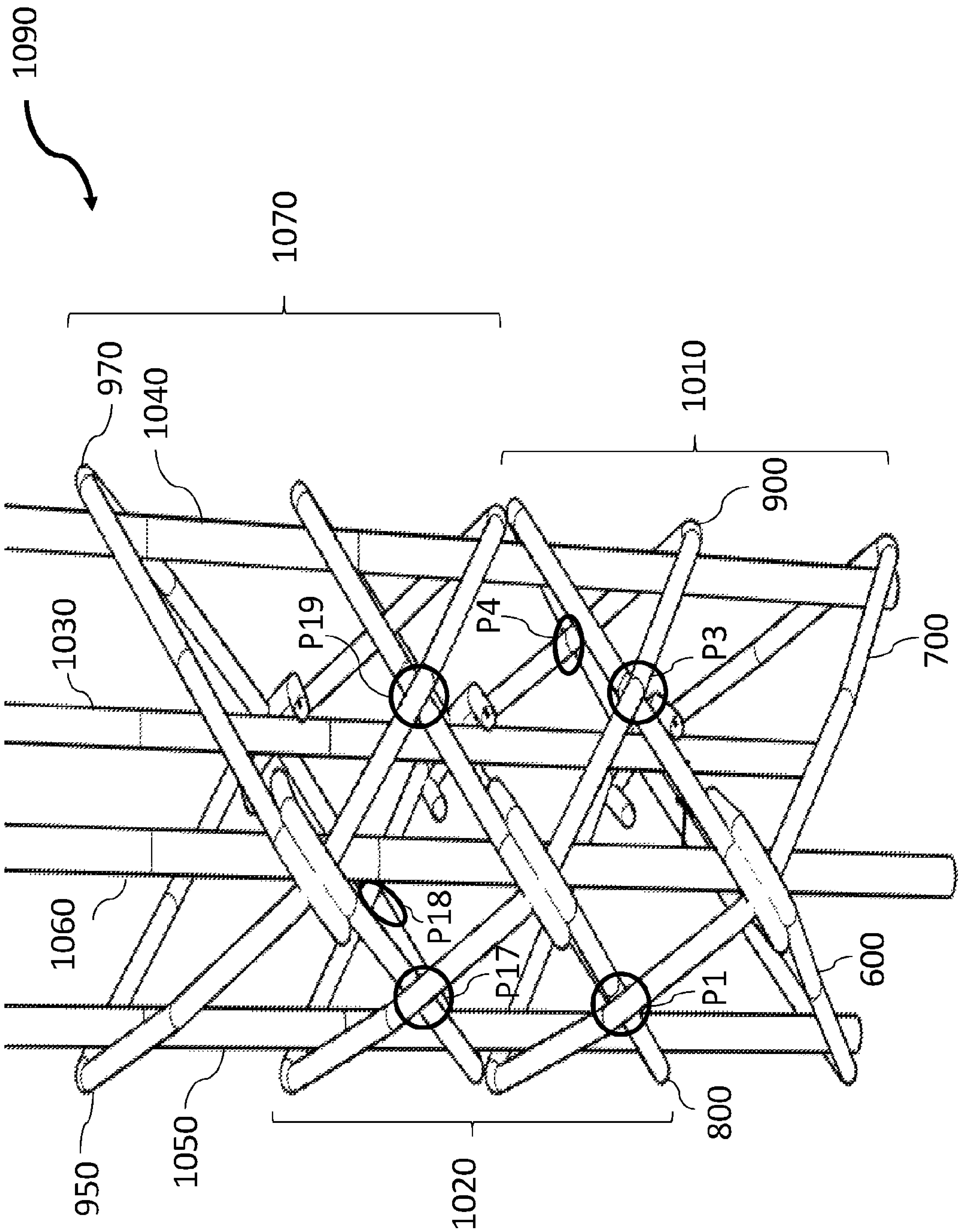

1000B
904
914
924
912
922
822
P4
804
H'/2
H'
814
824
P3
704
700
902
802
828
812
906
800
818
808
806
P2
816
826
P1
926
600
918
916
908
900
928
1010
1020

FIG.10B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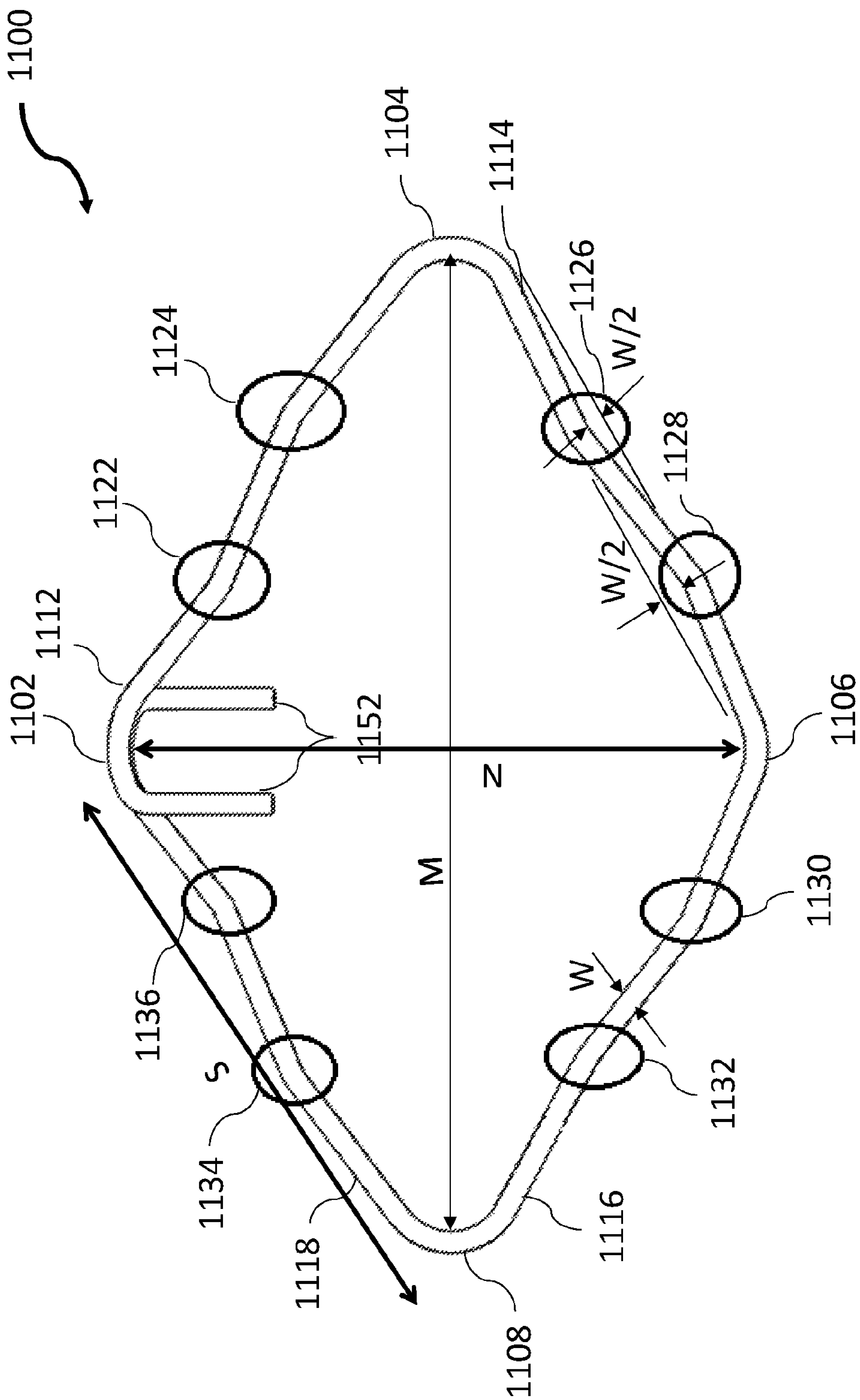
1070
1010
970
1040
900
1030
P19
P4
P3
700
1060
P18
P17
P1
600
950
1050
1020
800

FIG.10C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1128
W/2
1112
1102
1152
1106
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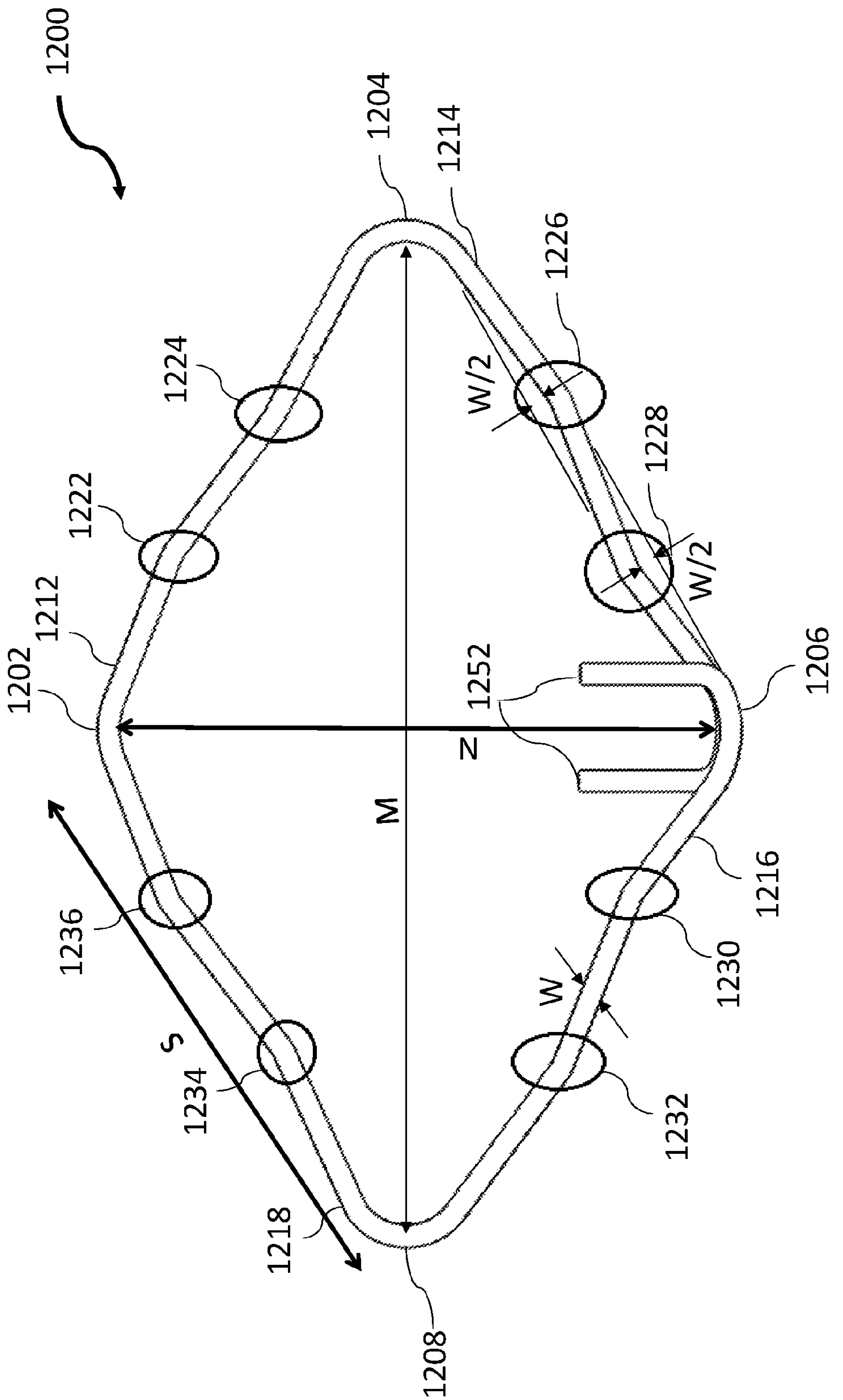
1136
1130
W
S
1134
1132
1118
1116
1108

FIG.11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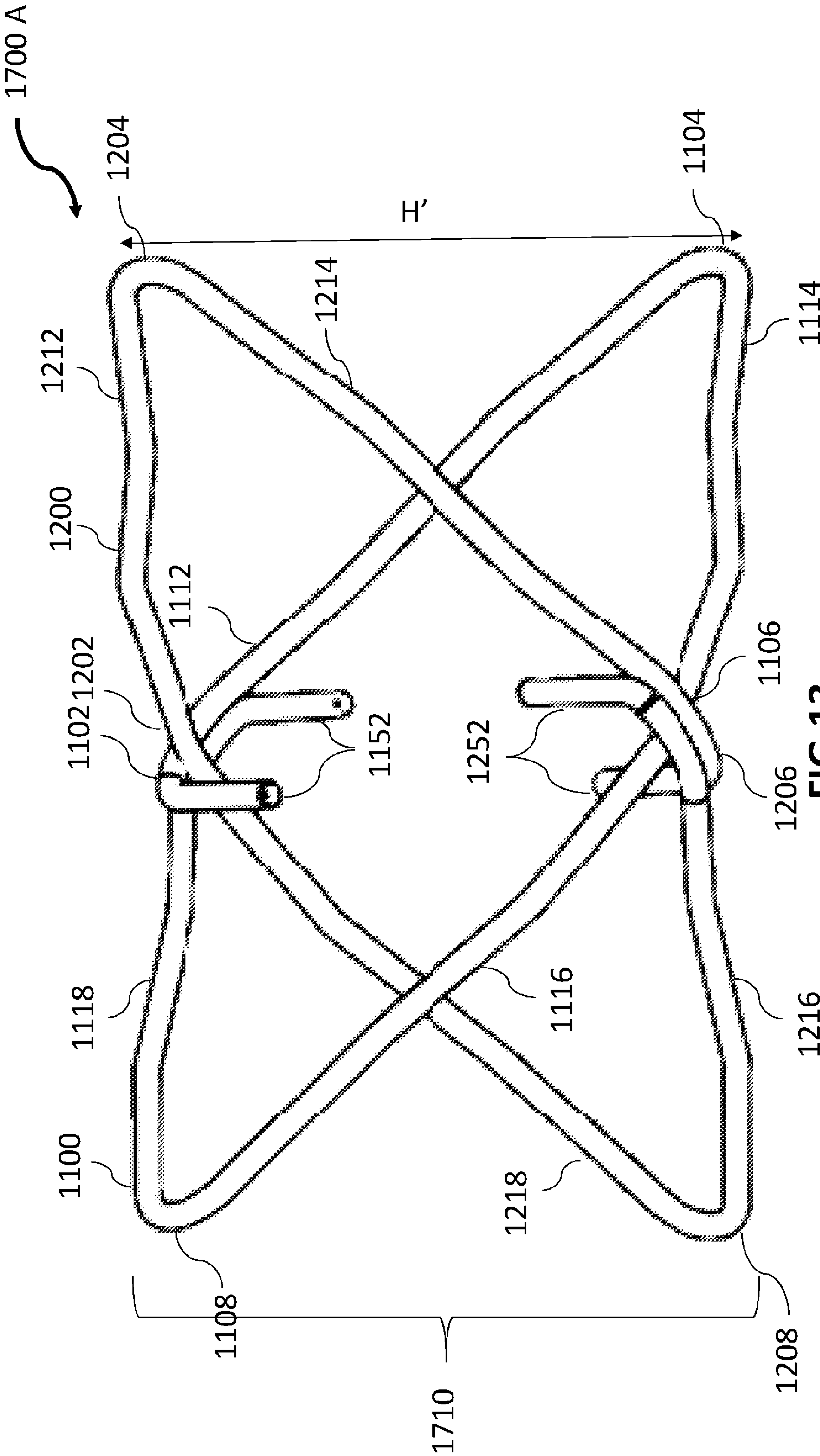
1228
1222
W/2
1212
1202
1252
1206
N
M
1236
1216
1230
W
S
1234
1232
1218
1208

FIG.12


1700 A
1204
1104
H'
1214
1212
1114
1200
1112
1202
1102
1152
1252
1106
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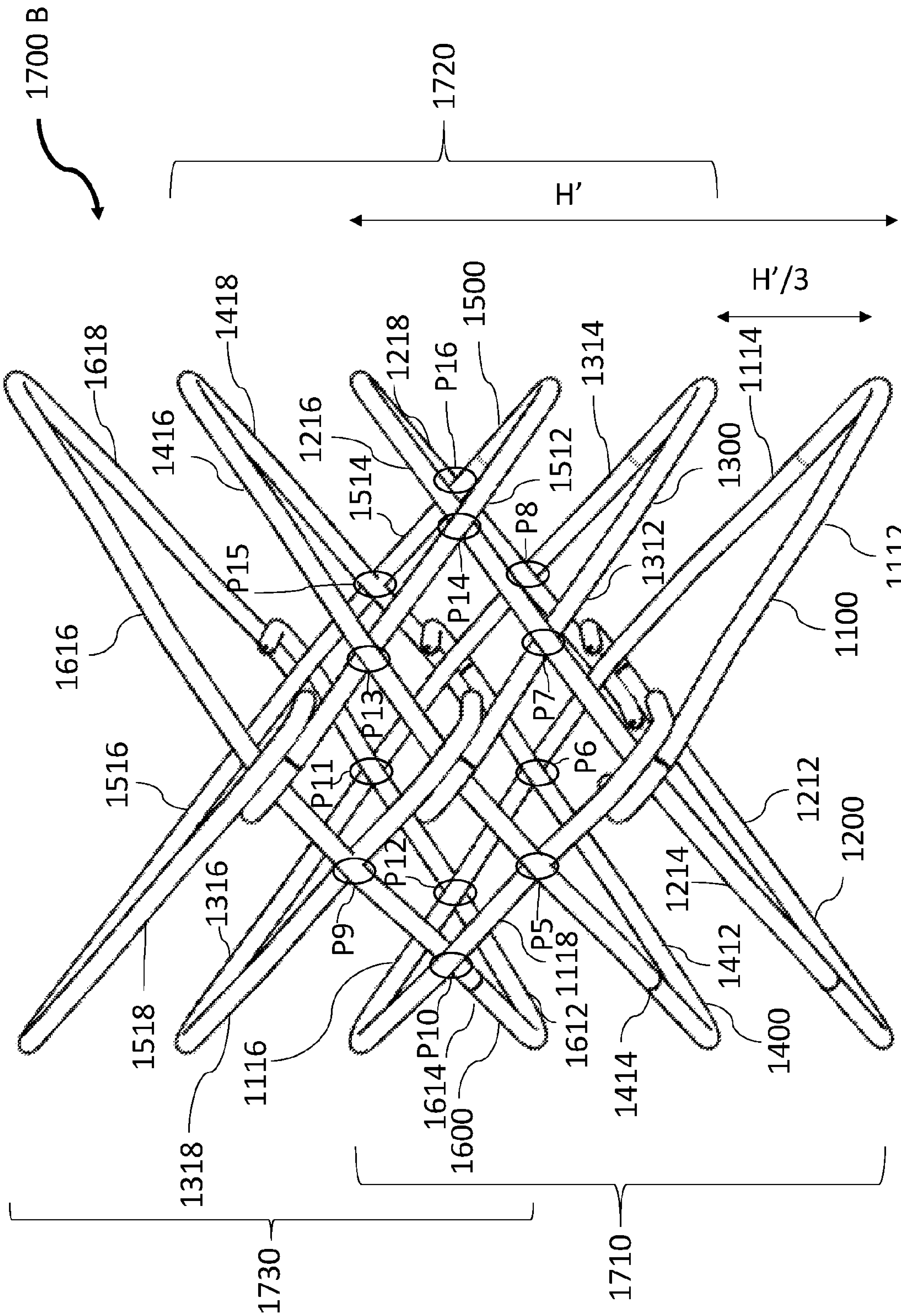
1218
1108
1208
1710

FIG.13


1700 B
1720
H'
H'/3
1730
1710
1618
1418
1218
1500
1314
1114
1416
1216
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1512
1300
1112
1100
1312
1616
1516
1316
1518
1318
1116
1614
1600
1612
1118
1414
1400
1412
1214
1200
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P5
P6
P7
P8
P9
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P12
P13
P14
P15
P16

FIG.14

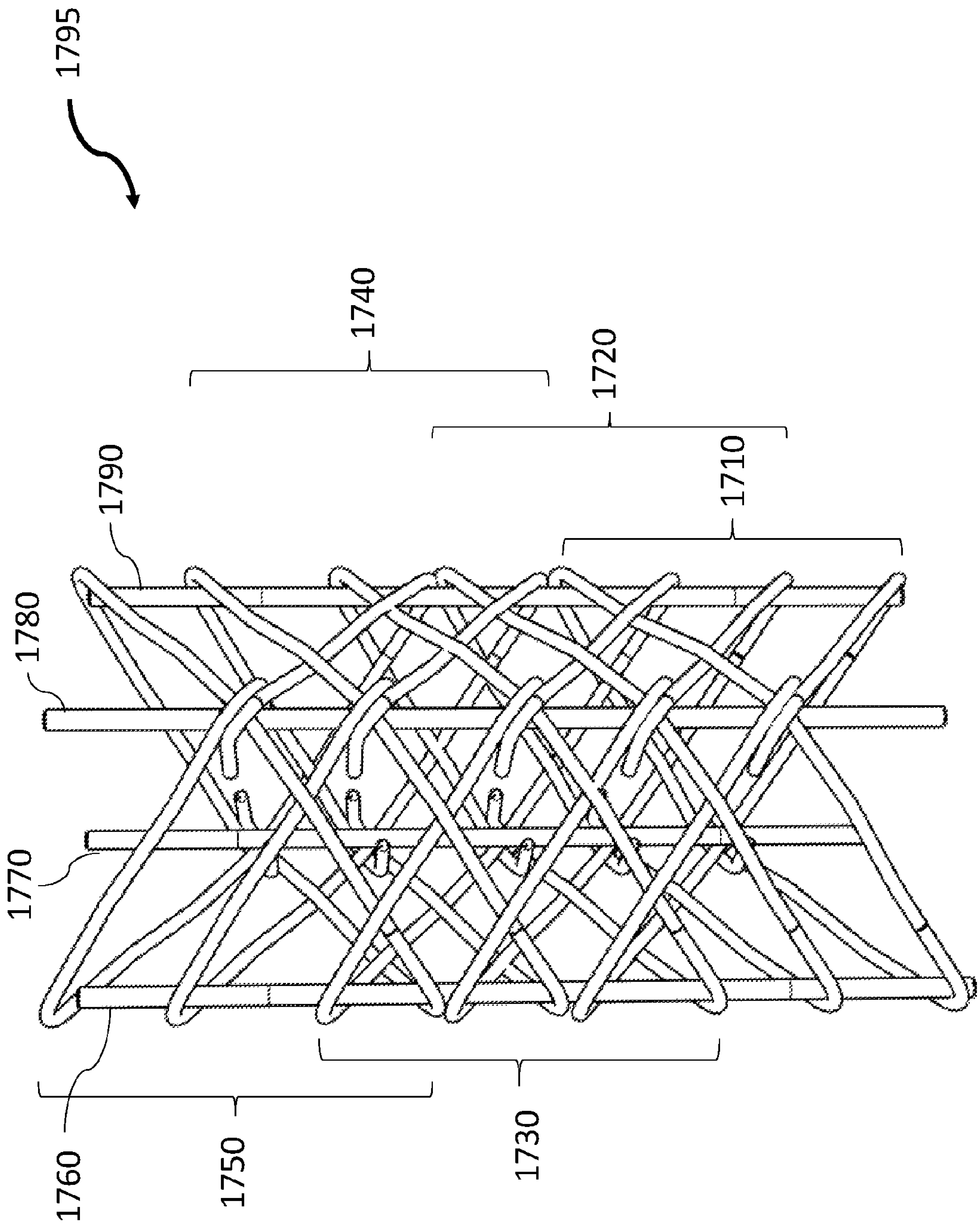


FIG.15

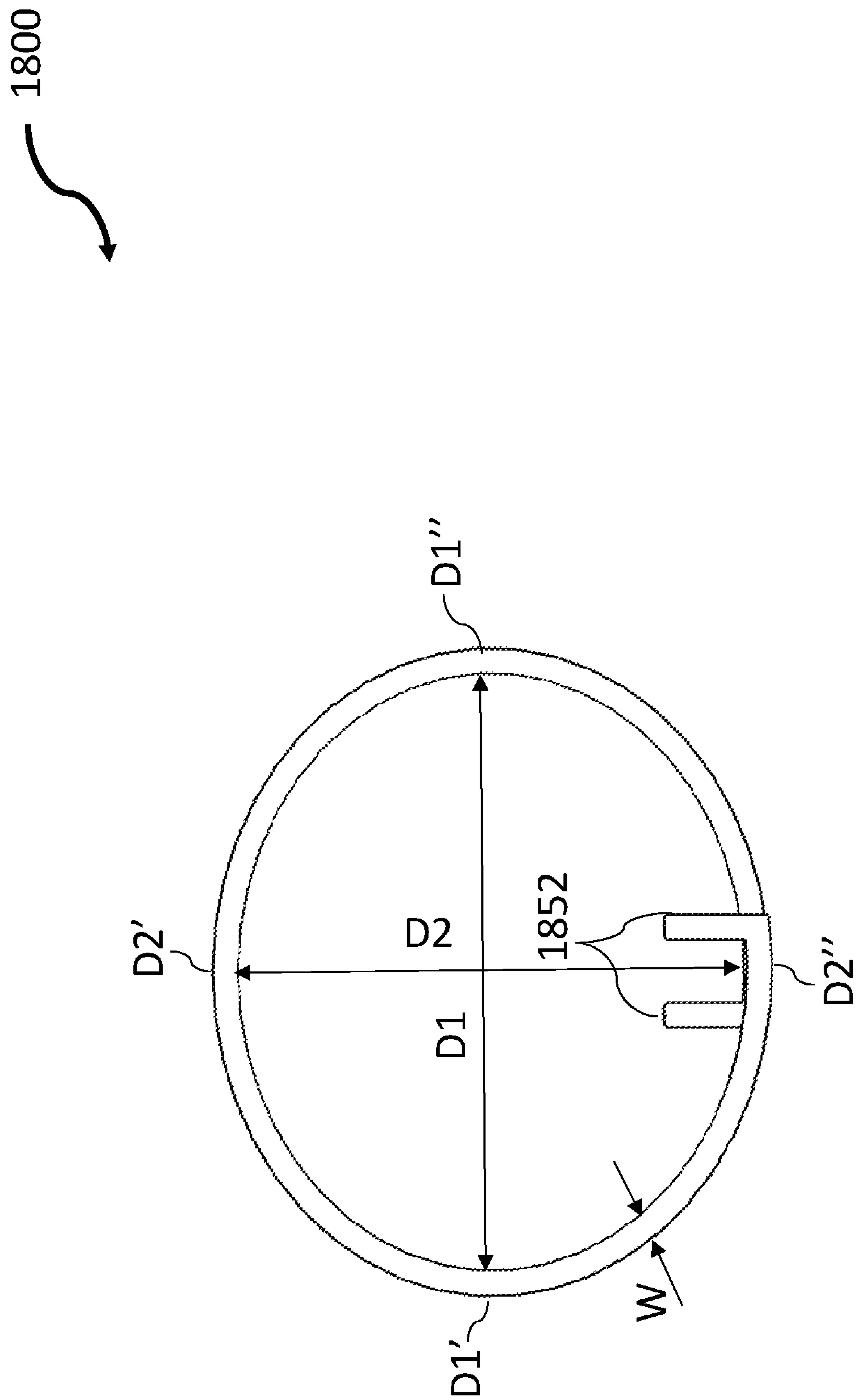
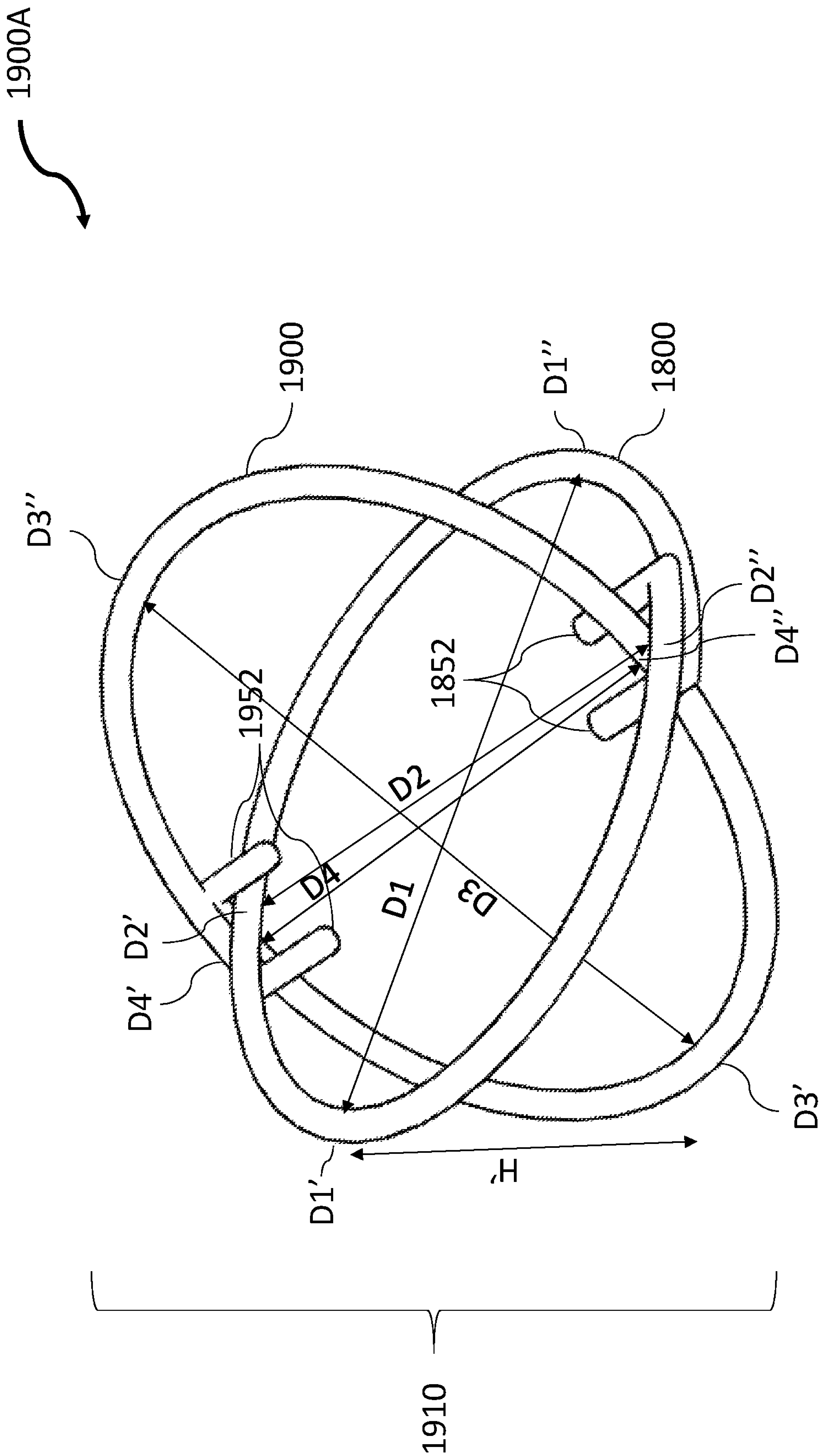


FIG.16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1900
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1800
D3''
D2''
D4''
1852
1952
D2
D4
D1
D3
D2'
D4'
D3'
D1'
H'
1910

FIG.17A

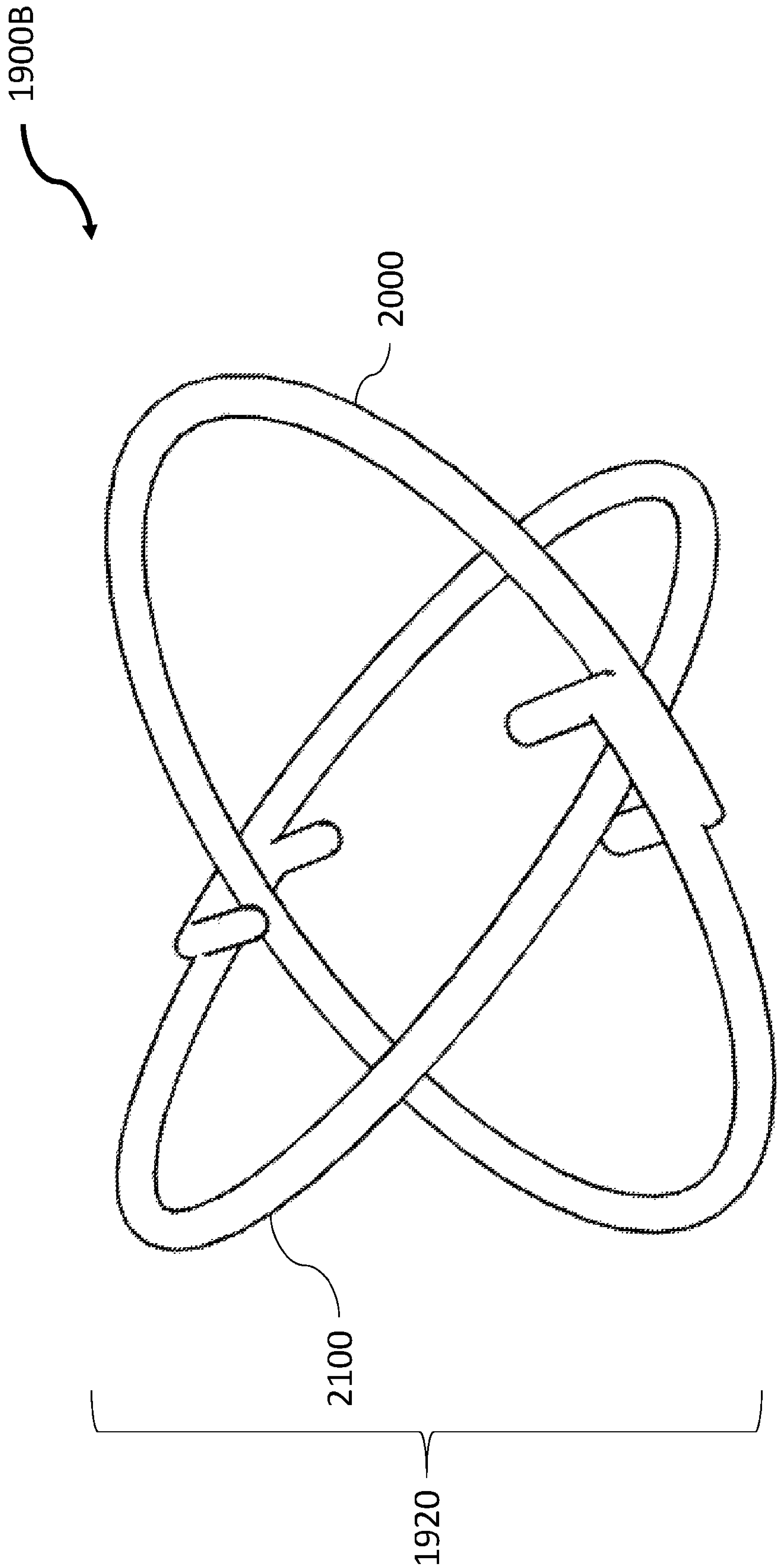
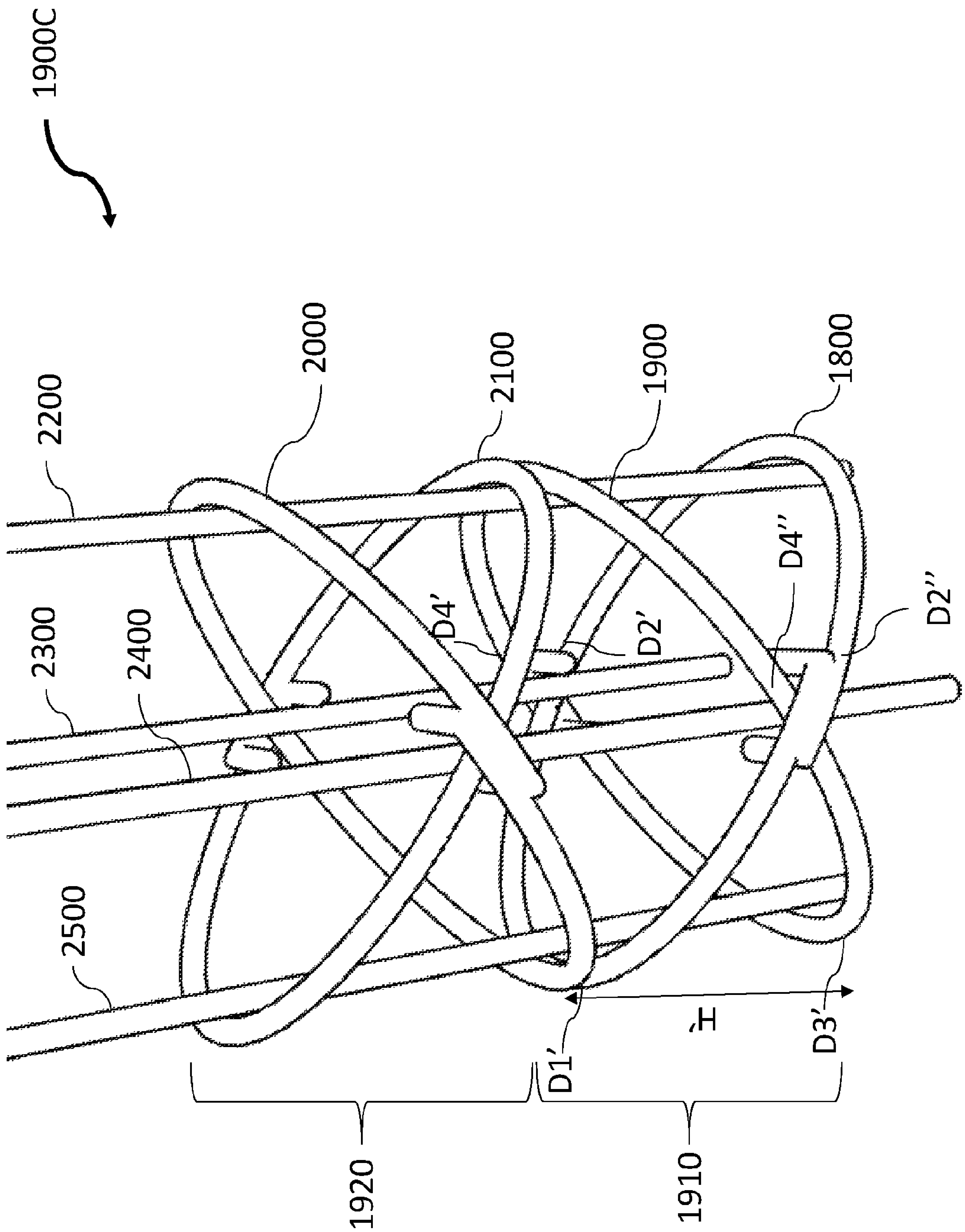


FIG.17B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2200
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2100
1900
1800
2300
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D4'
D2'
D4''
D2''
2500
D1'
H'
D3'
1920
1910

FIG.18

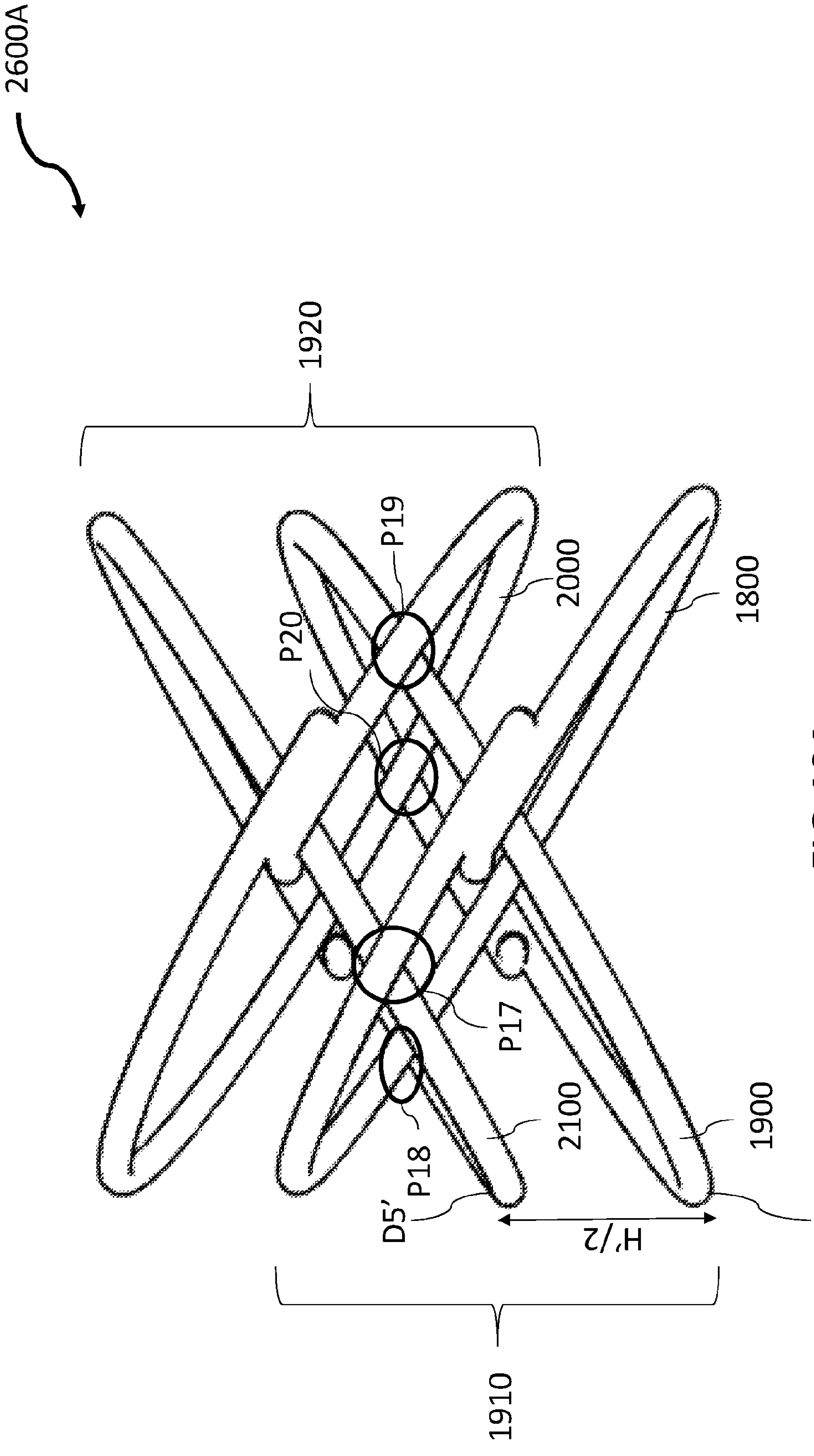
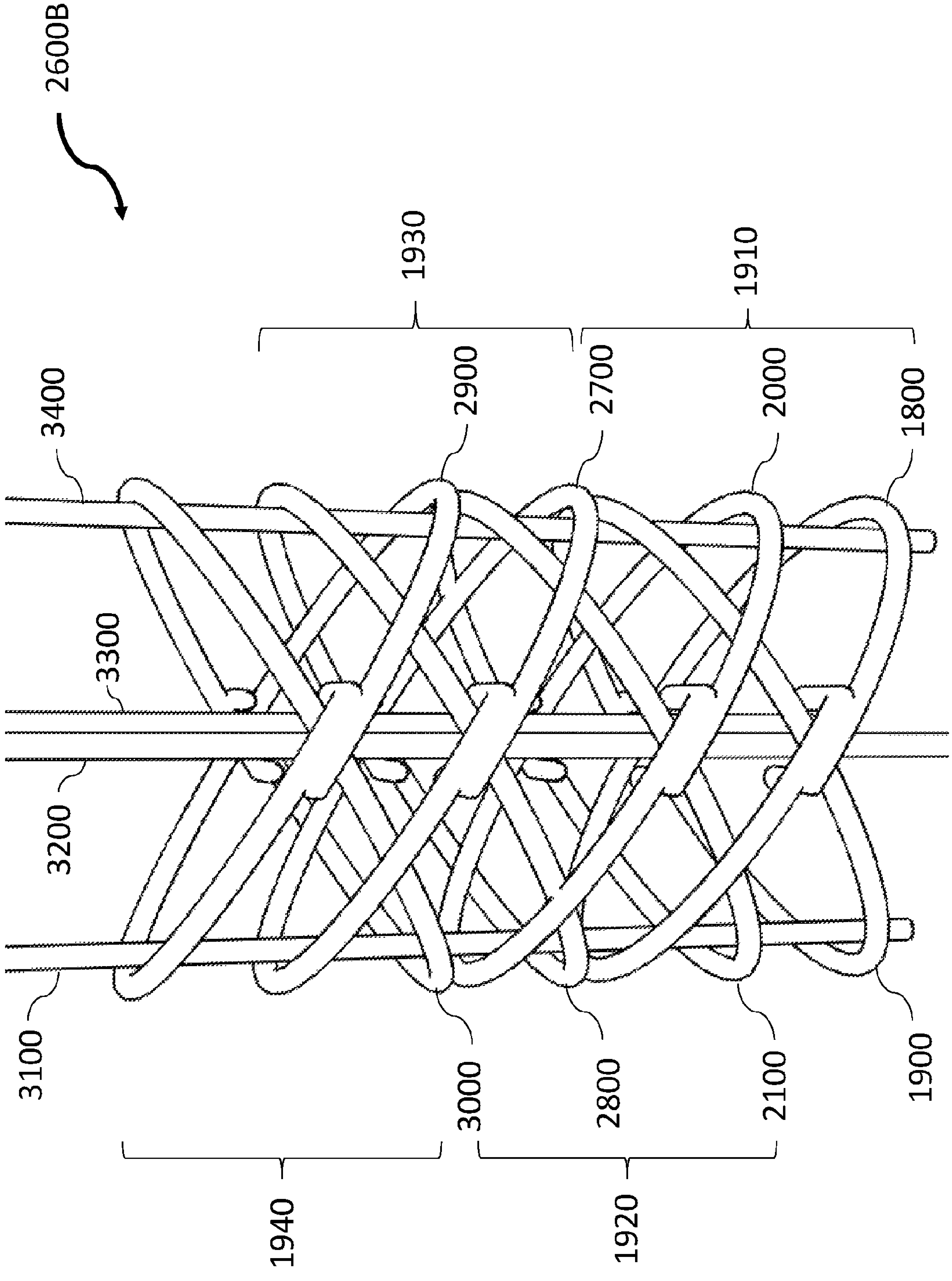


FIG.19A


2600B
1930
1910
3400
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2700
2000
1800
3300
3200
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3000
2800
2100
1900
1940
1920

FIG.19B

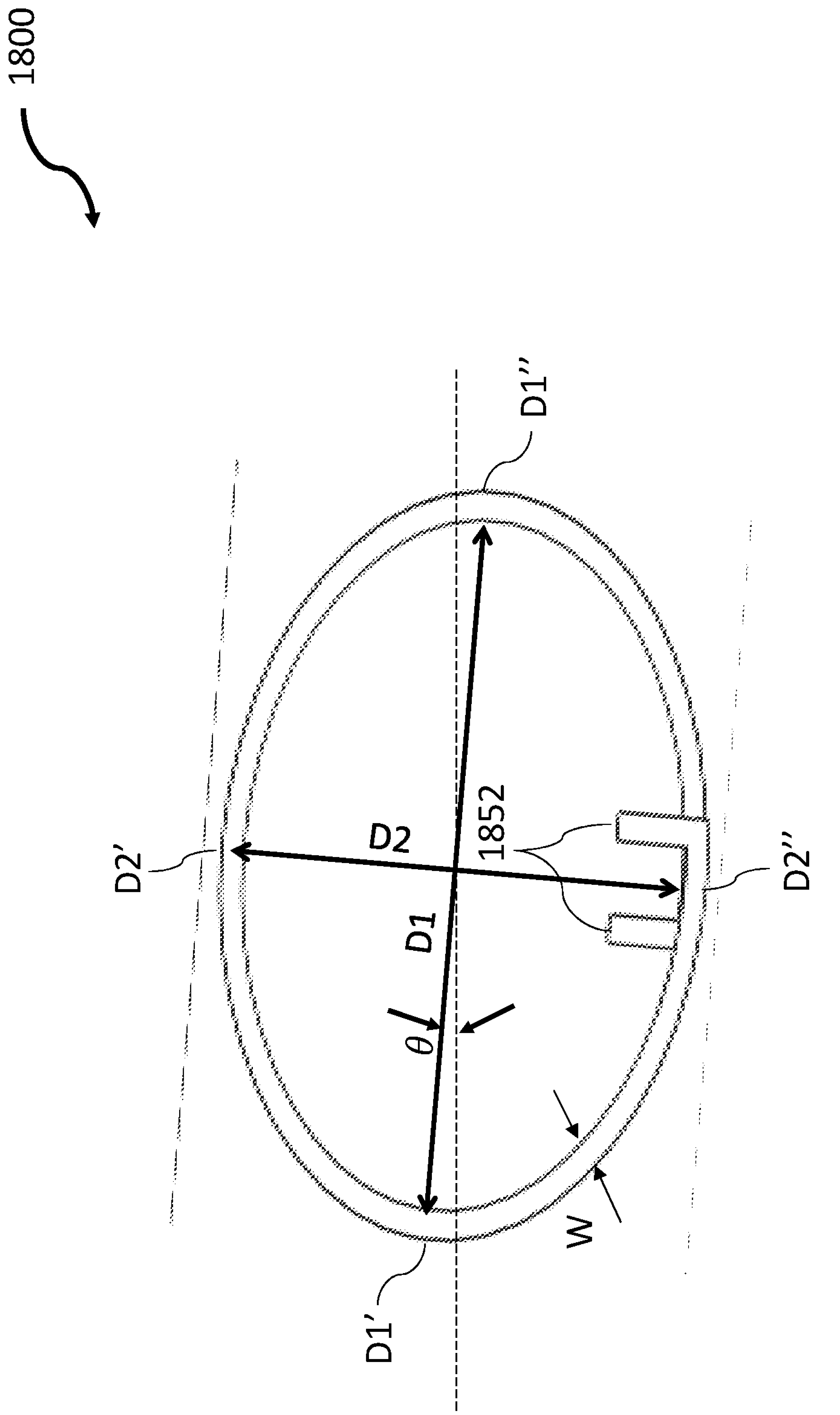

FIG.20

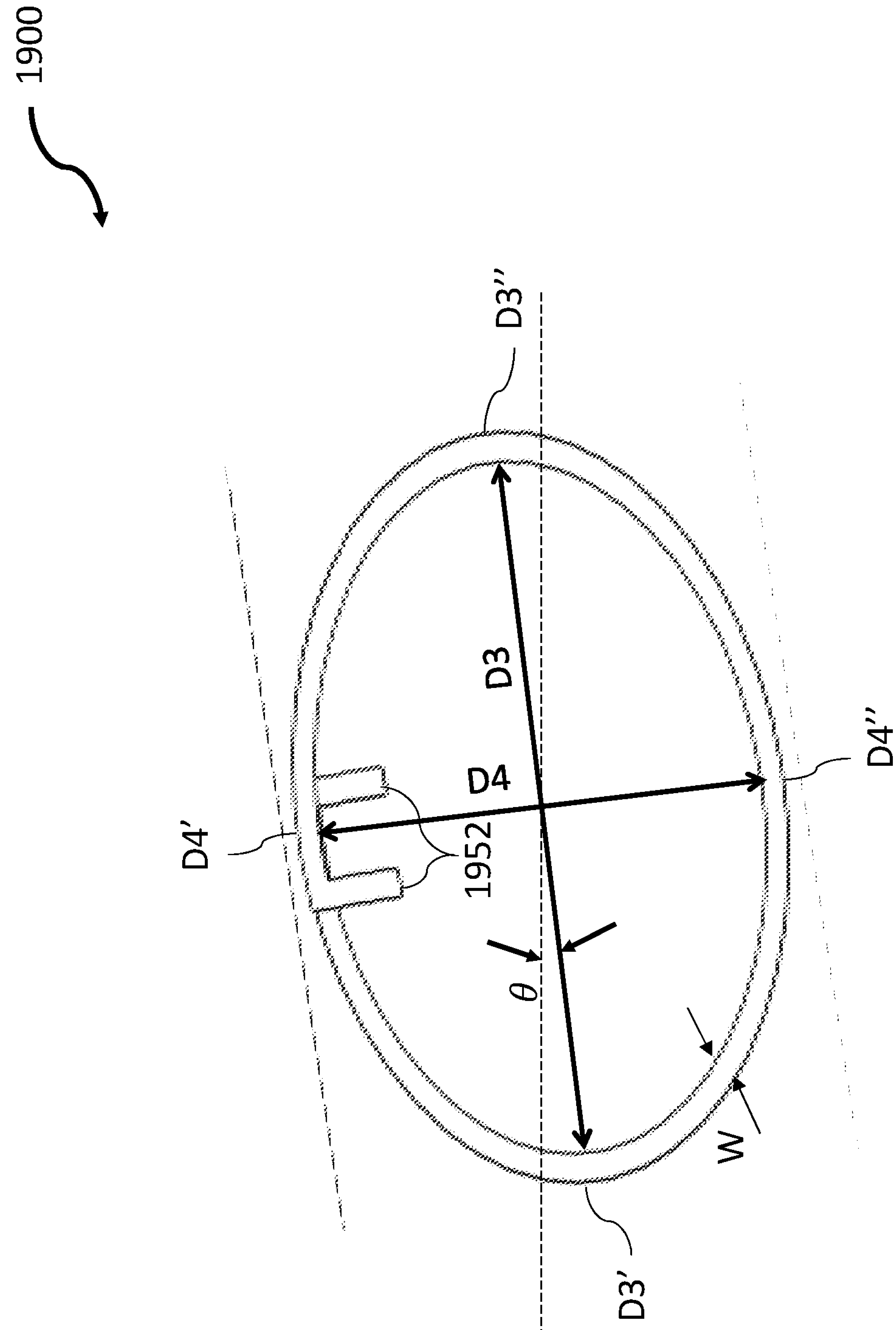

FIG.21

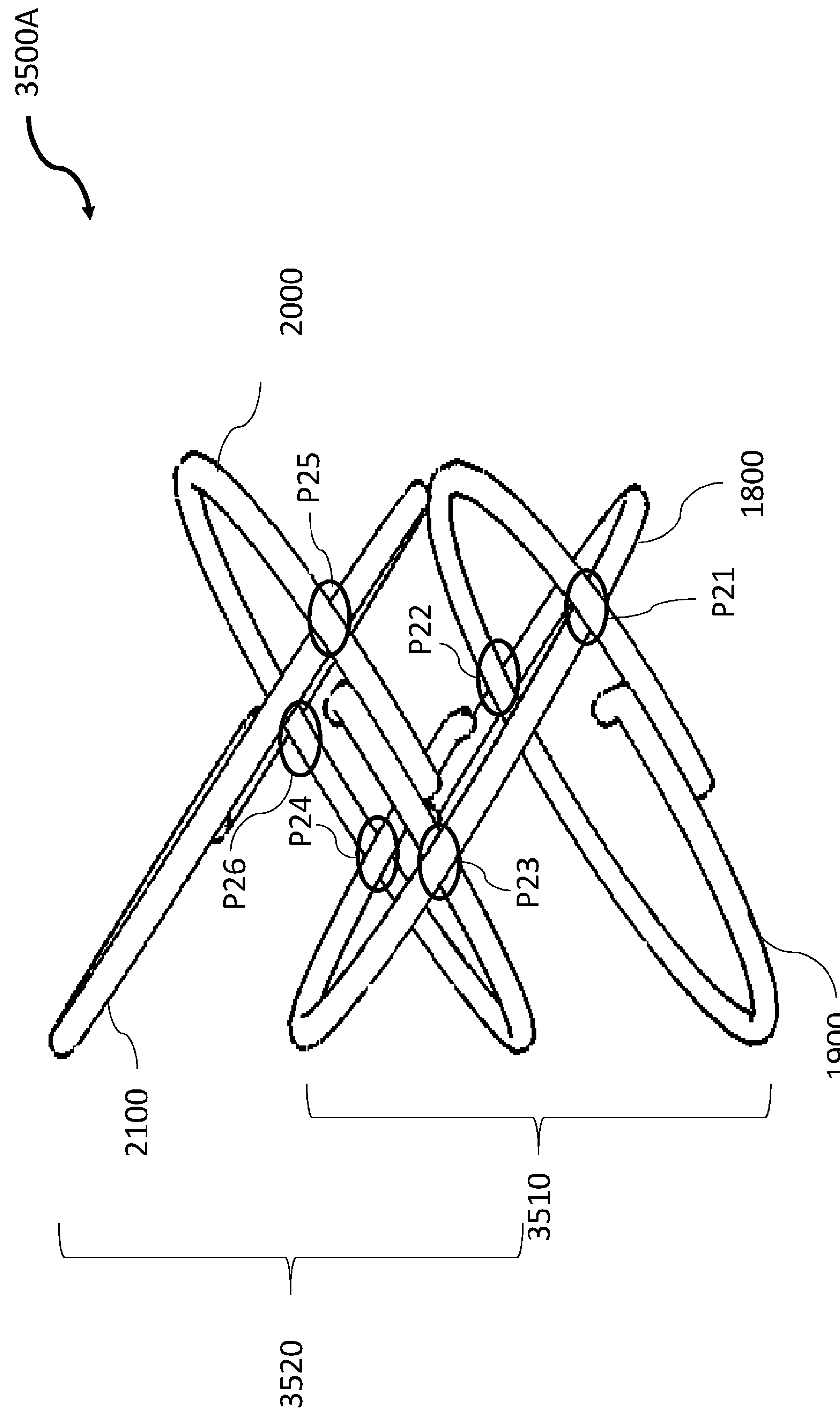

FIG.22A

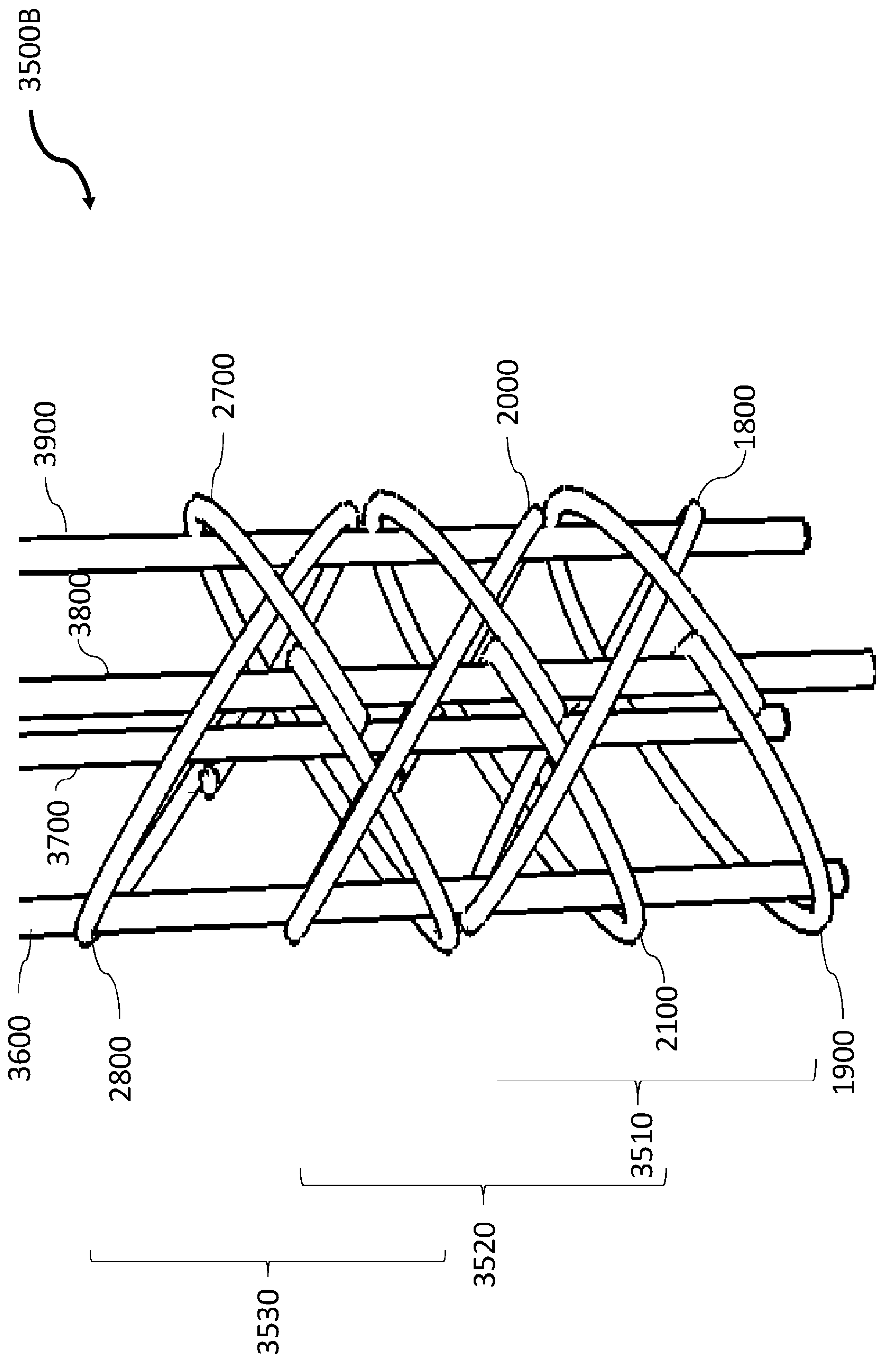
3500B
3900
2700
2000
1800
3800
3700
3600
2800
2100
1900
3510
3520
3530

FIG.22B

LATERAL REINFORCEMENT SYSTEM AND METHOD FOR CONCRETE STRUCTURES

FIELD OF THE INVENTION

The present invention relates to lateral reinforcement systems and methods for concrete structures.

BACKGROUND OF THE INVENTION

Various systems for reinforcing building structural components for making reinforced concrete structures have been proposed. Generally, steel reinforcing unit is embedded in the cast concrete for providing the concrete structure to improve tensile strength, compressive strength and shear capacity. Specifically, such systems include one or more stirrups or ties with a series of bars placed along the axis of the member to form a cage like apparatus. Such stirrups and ties constitute one of the most critical factors of quality and seismic resistance of buildings. Some of such existing stirrups/tie for reinforcing the building structural components are described herein.

As per the prior arts described herein, FIG. **1** (PRIOR ART) describes a concrete structure **10** in which conventional ties **2** are installed on the vertical bars **4** and convention stirrups **6** are installed on the horizontal bars **8**.

FIG. **2** (PRIOR ART) describes a conventional rectangular tie **20** (similar to conventional ties **2** or conventional stirrups bused in constructing a concrete structure (for example, the concrete structure **10**). Tie **20** is usually made of solid steel bars of circular cross section with a diameter 'd_b', length breadth 'B' and major diagonal dimension 'D'. Further, tie **20** comprises hooks **22** for anchoring the ties **20** to the load bearing element of the structure (for structures such as bars **8** of FIG. **1**). Such conventional ties **20** when disposed around the plurality of the vertical bars/horizontal bars form a cage like structure.

FIG. **3** (PRIOR ART) illustrates such cage like structure **30** wherein a plurality of conventional rectangular ties **20** is disposed around the vertical bars **32**. Specifically, the conventional rectangular ties **20** are placed one above the other parallel to the surface on which the vertical bars **32** are placed and perpendicular to the vertical bars **32**. Two rectangular ties **20** have a height difference (spacing) of 'h' between them.

Similarly, FIG. **4** (PRIOR ART) describes a conventional circular tie **40** (similar to conventional ties **2** or conventional stirrups **6**) used in constructing a concrete structure (for example, the concrete structure **10**). Tie **40** is usually made of solid steel bars of circular cross section having a diameter 'd_b', and cage diameter 'D'. Further, tie **40** comprises hooks **42** for anchoring the ties **40** to the load bearing element of the structure. Such conventional ties **40** when disposed around the plurality of the vertical bars/horizontal bars form a cage like structure.

FIG. **5** (PRIOR ART) illustrates such cage like structure **50** wherein a plurality of conventional circular ties **40** is disposed around the vertical bars **52**. Specifically, the conventional circular ties **40** are placed one above the other parallel to the surface on which the vertical bars **52** are placed and perpendicular to the vertical bars **52**. Two circular ties **40** have a height difference (spacing) of 'h' between them.

As illustrated in FIG. **1** (PRIOR ART), FIG. **3** (PRIOR ART) and FIG. **5** (PRIOR ART) the conventional configuration of the ties/stirrups only improves confinement of concrete at location of the ties/stirrups where it is disposed. Specifically, confinement received by concrete is localized and dependent on the spacing of the ties/stirrups. Improvement in such concrete confinement is achieved on reducing the spacing of ties/stirrups which results in heavy congestion and consumption of reinforcement steel.

Further, when subjected to an earthquake, requirement of steel reinforcement in the form of ties/stirrups increases to meet the additional demand. Conventional configuration of the ties/stirrups as illustrated in FIG. **1** (PRIOR ART), FIG. **3** (PRIOR ART) and FIG. **5** (PRIOR ART) is localized and confined to its own plane. In this case, resistance to opening of cracks provided by steel reinforcement is limited to the plane where the tie/stirrups are confined. This leads to strength degradation for cycle after cycle of the earthquake ground motion (vibration) or under impact loads. Likewise, when structural elements are subject to impact loads (such as blast), conventional tie pattern systems are not efficient to resist such loads.

Accordingly, there exists a need for a lateral reinforcement system that provides enhanced performance of concrete structures compared to the conventional patterns. Also, there exists a need of a lateral reinforcement system which utilizes less amount of steel, having improved constructability, possessing an enhanced load carrying capacity, having an enhanced earthquake resistance and energy absorption and is cost effective.

SUMMARY OF THE INVENTION

In view of the foregoing disadvantages inherent in the prior-art, the general purpose of the present invention is to provide a lateral reinforcement system and method for concrete structures that is configured to include all advantages of the prior art and to overcome the drawbacks inherent in the prior art offering some added advantages.

In one aspect, the present invention provides a system for a lateral reinforcement system for a concrete structure having axially disposed structural bars. The lateral reinforcement system comprises a plurality of reinforcement ties disposed at an inclination to the axially disposed structural bars. A pair of reinforcement ties of the plurality of reinforcement ties is disposed at mirror inclinations to each other. In the pair of reinforcement ties, cross each other at diametrically opposite corners of the reinforcement ties at diametrically opposite axially disposed structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from inside of the first reinforcement tie at the diametrically opposite structural bar. The plurality of reinforcement ties forms a three-dimensional interwoven network around the axially disposed structural bars.

In another aspect, the present invention provides a method for lateral reinforcement for concrete structures using the lateral reinforcement system of the present invention comprising the plurality of the reinforcement ties of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and features of the present invention will become better understood with reference to the following detailed description and claims taken in conjunction with the accompanying drawings, in which:

FIG. 1 (PRIOR ART) illustrates a concrete structure in which conventional ties are installed on the vertical bars and convention stirrups are installed on the horizontal bars;

FIG. 2 (PRIOR ART) illustrates a conventional rectangular tie;

FIG. 3 (PRIOR ART) illustrates a plurality of conventional rectangular ties of FIG. 2(PRIOR ART) disposed around a plurality of vertical bars;

FIG. 4 (PRIOR ART) illustrates a conventional circular tie;

FIG. 5 (PRIOR ART) illustrates a plurality of conventional circular ties of FIG. 4 (PRIOR ART) disposed around a plurality of vertical bars;

FIG. 6. illustrates a rhombical reinforcement tie, in accordance with an exemplary embodiment of the present invention;

FIG. 7 illustrates a pair of rhombical reinforcement ties of FIG. 6 forming a reinforcement tie unit;

FIG. 8 illustrates a lateral reinforcement system comprising a plurality of rhombical reinforcement ties of FIG. 6 forming a three-dimensional interwoven network around a plurality of axially disposed structural bars;

FIGS. 9A and 9B illustrates a pair of mid-side kinked rhombical reinforcement ties, in accordance with another exemplary embodiment of the present invention;

FIG. 10A illustrates the pair of mid-side kinked rhombical reinforcement ties of FIGS. 9A and 9B forming a reinforcement tie unit;

FIG. 10B illustrates two pairs of mid-side kinked rhombical reinforcement ties of FIGS. 9A and 9B forming multi-layered reinforcement tie unit, each pair having intersection with subsequent pair at mid side;

FIG. 10C illustrates a lateral reinforcement system comprising a plurality of mid-side kinked rhombical reinforcement ties of FIGS. 9A and 9B forming multi-layered reinforcement tie unit (as in FIG. 10B) and consequently a three-dimensional interwoven network around a plurality of axially disposed structural bars;

FIGS. 11 and 12 illustrate a pair of one-third side kinked rhombical reinforcement ties, in accordance with another exemplary embodiment of the present invention;

FIG. 13 illustrates a pair of mid-side kinked rhombical reinforcement ties of FIGS. 11 and 12 forming a reinforcement tie unit, in accordance with an exemplary embodiment of the present invention;

FIG. 14 illustrates three pairs of mid-side kinked rhombical reinforcement ties of FIGS. 11 and 12 forming multi-layered reinforcement tie unit, each pair having intersection with subsequent pair at one-third of the sides;

FIG. 15 illustrates a lateral reinforcement system comprising a plurality of one-third side kinked rhombical reinforcement ties of FIGS. 11 and 12 forming multi-layered reinforcement tie unit (as in FIG. 14) and consequently a three-dimensional interwoven network around a plurality of axially disposed structural bars;

FIG. 16 illustrates an elliptical reinforcement tie, in accordance with an exemplary embodiment of the present invention;

FIG. 17A illustrates a pair of elliptical reinforcement ties of FIG. 16 forming a reinforcement tie unit, in accordance with an exemplary embodiment of the present invention;

FIG. 17B illustrates a pair of elliptical reinforcement ties of FIG. 16 forming a reinforcement tie unit mirror image to the reinforcement tie unit of FIG. 17A, in accordance with an exemplary embodiment of the present invention;

FIG. 18 illustrates a lateral reinforcement system comprising a plurality of elliptical reinforcement ties of FIG. 16 forming a three-dimensional interwoven network around a plurality of axially disposed structural bars;

FIG. 19A illustrates two pairs of elliptical reinforcement ties of FIG. 16 forming a multi-layered reinforcement tie unit 2600A;

FIG. 19B illustrates a lateral reinforcement system comprising a plurality of elliptical reinforcement ties of FIG. 16 forming a three-dimensional interwoven network around a plurality of axially disposed structural bars;

FIG. 20 illustrates an elliptical reinforcement tie similar to the reinforcement tie of FIG. 16 and rotated clockwise by a pre-determined angle, in accordance with an exemplary embodiment of the present invention;

FIG. 21 illustrates an elliptical reinforcement tie that is a mirror image of the reinforcement tie of FIG. 20 and rotated counter-clockwise by the pre-determined angle, in accordance with an exemplary embodiment of the present invention;

FIG. 22A illustrates two pairs of elliptical reinforcement ties of FIGS. 20 and 21 forming a multi-layered reinforcement tie unit 3500A; and

FIG. 22B illustrates is a lateral reinforcement system comprising a plurality of elliptical reinforcement ties of FIGS. 20 and 21 forming a three-dimensional interwoven network around a plurality of axially disposed structural bars.

DETAILED DESCRIPTION OF THE INVENTION

The exemplary embodiments described herein detail for illustrative purposes are subject to many variations. It should be emphasized, however that the present invention is not limited to particular lateral reinforcement system and method for concrete structures as described. Rather, the principles of the present invention may be used with a variety of configurations and structural arrangements of the lateral reinforcement system. It is understood that various omissions, substitutions of equivalents are contemplated as circumstances may suggest or render expedient, but the present invention is intended to cover the application or implementation without departing from the spirit or scope of the its claims.

In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without these specific details.

As used herein, the term 'plurality' refers to the presence of more than one of the referenced item and the terms 'a', 'an', and 'at least' do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

The present invention provides a lateral reinforcement system for concrete structures comprising structural bars. Such structural bars include vertical bars (for example, columns, piers, shear walls and the like) and horizontal bars (for example, beams, girders, and the like). For a person skilled in the art in the field of structural systems for buildings, bridges and bunkers, 'lateral reinforcement' as used herein is defined as the process used for holding the structural bars (horizontal bars and/or vertical bars) in proper alignment and to confine concrete and provide resistance to applied shear. As used herein, a 'vertical bar' refers to an upright structural member of metal in vertical members in buildings whose length is substantially greater than width. The vertical bars are usually employed for supporting a concentrated load in the buildings. Also, as used herein, a 'horizontal bar' refers to a reinforcing bar placed in a horizontal alignment along the length of the member that supports transverse load and transfers the load to vertical members.

The lateral reinforcement system of the present invention comprises a plurality of individual lateral reinforcement units, such as, ties, stirrups, rings, hoops, and the like. Also, for purposes of this disclosure and as known in the art, a lateral reinforcement unit in case of vertical bars is called a 'tie' and in case of horizontal bars is called a 'stirrup'. Hereinafter, for consistency in terminology in the description of the present invention, the individual lateral reinforcement units are referred to as 'reinforcement tie' or 'reinforcement ties'; and it will be evident to a person skilled in the art that the term 'reinforcement tie' or 'reinforcement ties' would collectively refer to one or more from the group of ties, stirrups, rings, hoops, and the like.

Specifically, the lateral reinforcement system of the present invention comprises a plurality ties forming a three-dimensional interwoven network around a plurality of axially disposed structural bars in a structure. Such a structure formed by the lateral reinforcement system around the structural bars when embedded in concrete, provides enhanced performance of concrete structures, constructability, enhanced load carrying capacity, enhanced earthquake resistance, enhanced energy absorption and saving in material (for example, steel) usage. Also, the present invention provides for a more efficient use of steel while providing enhancement of performance of reinforced concrete elements.

The lateral reinforcement system of the present invention comprises a plurality of reinforcement ties disposed at an inclination to the axially disposed structural bars. A pair of reinforcement ties of the plurality of reinforcement ties is disposed at mirror inclinations to each other. In the pair of reinforcement ties, the reinforcement ties cross each other at diametrically opposite corners of the reinforcement ties at diametrically opposite axially disposed structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from inside of the first reinforcement tie at the diametrically opposite structural bar. The plurality of reinforcement ties forms a three-dimensional interwoven network around the axially disposed structural bars.

Different embodiments of the present invention with regard to the different shapes, size and configuration of the reinforcement ties are explained herein below.

Referring to FIG. **6**, in one embodiment, illustrated is a rhombical reinforcement tie **100**. As used herein, "rhombical reinforcement tie" refers to a reinforcement tie in shape of a rhombus or diamond (or any quadrilateral shape as per the shape of vertical member/horizontal member). The rhombical reinforcement tie **100** is made of solid steel bar (or any other metallic/non-metallic bar) having a circular cross section of diameter W. The rhombical reinforcement tie **100** comprises four corners **102**, **104**, **106** and **108**; and four sides **112**, **114**, **116** and **118**. Each side **112**, **114**, **116**, **118** has a length S. As shown in FIG. **6**, the rhombical reinforcement tie **100** has a diagonal dimension M along a major axis and a diagonal dimension N along a minor axis. It will be evident to a person skilled in the art that the dimension nomenclature W, S, M and N are only for illustration and description purposes and the invention is not limited by such dimension nomenclature.

Further, the rhombical reinforcement tie **100** comprises a dual hook member **152** disposed at one of the corners of the rhombical reinforcement tie **100**. As shown in FIG. **6**, the dual hook member **152** is disposed at the corner **102** of the rhombical reinforcement tie **100**. The dual hook member **152** provides for anchoring the rhombical reinforcement tie **100** to the load bearing element of the structural bars. Further, the dual hook member **152** provides for engaging a corner of another rhombical reinforcement tie.

Referring to FIG. **7**, illustrated is a pair of rhombical reinforcement ties of FIG. **6** forming a reinforcement tie unit **450**. In FIG. **7**, the rhombical reinforcement ties are a first rhombical reinforcement tie **100** and a second rhombical reinforcement tie **200**. The second rhombical reinforcement tie **200** is similar to the first rhombical reinforcement tie **100** in shape and dimension, as described with reference to FIG. **6** (however, a mirrored image of reinforcement tie **100**). Specifically, the second rhombical reinforcement tie **200** comprises four corners **202**, **204**, **206** and **208**; and four sides **212**, **214**, **216** and **218**. Further, the second rhombical reinforcement tie **200** comprises a dual hook member **252** at the corner **202** of the second rhombical reinforcement tie **200**. The dual hook member **252** provides for anchoring the rhombical reinforcement tie **100** to the load bearing element of the structural bars. Further, the dual hook member **252** provides for engaging a corner of another rhombical reinforcement tie.

For forming the reinforcement tie unit **450**, the rhombical reinforcement ties **100**, **200** are disposed at mirror inclinations to each other, such that, the rhombical reinforcement ties are rotated about diagonal N (not shown in the FIG.) and cross each other at diametrically opposite corners of the rhombical reinforcement ties, thereby configuring two non-intersecting crossings.

In a first crossing, the first rhombical reinforcement tie **100** crosses from inside of the second rhombical reinforcement tie **200**. Specifically, the corner **106** of the first rhombical reinforcement tie **100** is on the inside and the corner **202** of the second rhombical reinforcement tie **200** is on outside. In this configuration, the dual hook **252** of the second rhombical reinforcement tie **200** engages the corner **106** of the first rhombical reinforcement tie **100**.

In a second crossing, the second rhombical reinforcement tie **200** crosses from inside of the first rhombical reinforcement tie **100**. Specifically, the corner **206** of the second rhombical reinforcement tie **200** is on the inside and the corner **102** of the first rhombical reinforcement tie **100** is on outside. In this configuration, the dual hook **152** of the first rhombical reinforcement tie **100** engages the corner **206** of the second rhombical reinforcement tie **200**.

Now, referring to FIG. **8**, illustrated is a lateral reinforcement system **500** comprising a plurality of rhombical reinforcement ties of FIG. **6** forming a three-dimensional interwoven network around a plurality of axially disposed structural bars **530**, **540**, **550** and **560**. In the lateral reinforcement system **500**, the rhombical reinforcement ties **100**, **200**, **300** and **400** are disposed at an inclination to the axially disposed structural bars **530**, **540**, **550** and **560**. That is, the rhombical ties **100**, **200**, **300**, **400** are disposed at an angle to the axially disposed structural bars **530**, **540**, **550** and **560** making it also inclined at an angle to a surface on which the axially disposed structural bars **530**, **540**, **550** and **560** are disposed. The rhombical reinforcement ties **300** and **400** are similar to the rhombical reinforcement ties **100** and **200** as described with reference to FIGS. **6** and **7**.

In this configuration, the reinforcement ties in a pair of reinforcement ties cross each at diametrically opposite corners of the reinforcement ties at diametrically opposite structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from inside of the first reinforcement tie at the diametrically opposite structural bar. For example, in a first crossing, the rhombical reinforcement tie **100** (first reinforcement tie) crosses from inside of the rhombical reinforcement tie **200** (second reinforcement tie) at the structural bar **550**. In this crossing, the corner **106** of the rhombical reinforcement tie **100** is on the inside and the corner **202** of the rhombical reinforcement tie **200** is on outside. Further, in a second crossing, the second rhombical reinforcement tie **200** (second reinforcement tie) crosses from inside of the first rhombical reinforcement tie **100** (first reinforcement tie) at diametrically opposite structural bar **540**. In this crossing, the corner **206** of the second rhombical reinforcement tie **200** is on the inside and the corner **102** of the first rhombical reinforcement tie **100** is on outside. Accordingly, the pair of rhombical reinforcement ties **100**, **200** is configured to form two non-intersecting crossings at the diametrically opposite structural bars **540**, **550**.

The pair of rhombical reinforcement ties **300**, **400** is configured in a similar manner.

For forming the lateral reinforcement system **500**, a plurality of reinforcement tie units (such as the reinforcement tie unit **450**) are disposed on and the about the axially disposed structural bars **530**, **540**, **550**, and **560**. The process comprises placing a first reinforcement tie unit and then another reinforcement tie unit on top of the first reinforcement tie unit, and so on. For example, the first reinforcement tie unit (herein referred to as reinforcement tie unit **450**) is formed by rhombical reinforcement ties **100**, **200** configured about each other and about the axially disposed structural bars **530**, **540**, **550**, and **560** as explained above. Next, a second reinforcement tie unit is formed by rhombical reinforcement ties **300**, **400** and is placed over the first reinforcement tie unit **450**.

In this formation, the plurality of rhombical reinforcement ties **100**, **200**, **300**, and **400** form a three-dimensional interwoven network around the axially disposed structural bars **530**, **540**, **550**, and **560**. The three-dimension interwoven network is a collection of sub-interwoven networks formed by individual reinforcement tie units. For example, as illustrated in FIG. **8**, a first sub-interwoven network **510** is formed by the first reinforcement tie unit **450**, and a second sub-interwoven network **520** is formed by the second reinforcement tie unit (not numbered herein). Although, in FIG. **8** herein, illustrated are only two reinforcement tie units forming two sub-interwoven networks, it will be evident to a person skilled in the art that the lateral reinforcement system can comprise more than two sub-interwoven networks as per the shape and size requirements of the structural bars and reinforcement requirement for a concrete structure.

Further, as illustrated in FIG. **8**, the rhombical reinforcement ties **100**, and **200** are at mirror inclinations to each other such that a distance (spacing) between corners of the rhombical ties **100**, and **200** on the same structural bar is a pre-determined height H. Specifically, as illustrated in FIG. **8**, 'H' is the distance between corner **104** of the rhombical reinforcement tie **100** and corner **208** of the rhombical reinforcement tie **200** on the structural bar **560**.

Referring to FIGS. **9**A and **9**B, in another embodiment, illustrated is a pair of mid-side kinked rhombical reinforcement ties **600** and **700** respectively. As used herein, "mid-side kinked rhombical reinforcement tie" refers to a tie in shape of rhombus or diamond having kink at the midpoint of the each four sides of the rhombical reinforcement tie. Further as used herein, "kink" is defined as a sharp twist or curve or deviation in the sides of something (here rhombical tie/stirrup) that is otherwise straight.

The reinforcement tie **600** is made of steel bar (or any other metallic/non-metallic bar) having a circular cross section of diameter W. The reinforcement tie **600** comprises four corners **602**, **604**, **606** and **608**; and four sides **612**, **614**, **616** and **618**. Each side **612**, **614**, **616** and **618** has a length S. As shown in FIG. **9**A, the reinforcement tie **600** has a diagonal dimension M along a major axis and a diagonal dimension N along a minor axis. It will be evident to a person skilled in the art that the dimension nomenclature W, S, M and N are only for illustration and description purposes and the invention is not limited by such dimension nomenclature.

Further, the reinforcement tie **600** comprises a dual hook member **652** disposed at one of the corners of the reinforcement tie **600**. As shown in FIG. **9**A, the dual hook member **652** is disposed at the corner **602** of the reinforcement tie **600**. The dual hook member **652** provides for anchoring the reinforcement tie **600** to the load bearing element of the structural bars. Further, the dual hook member **652** provides for engaging a corner of another reinforcement tie.

Further, the reinforcement tie **600** comprises of kinks **622**, **624**, **626** and **628** at the midpoint of the four sides **612**, **614**, **616** and **618** respectively having a deviation dimension W/2, that is, a kink with a deviation dimension of half the cross-sectional diameter of the bar making the reinforcement tie **600**. It will be evident to a person skilled in the art that the deviation dimension is not limited to W/2 and can vary as per the configurational and reinforcement requirements.

As used herein, kinks are formed on reinforcement ties is to facilitate crossing of the other reinforcement ties in a vertical planes. As explained further herein, the reinforcement ties themselves form a geometric pattern with kinks all in one plane. The pattern is formed by crossing the ties in vertical plane with crossing points identified by the kinks.

Specifically the kink **622** at the side **612** is a low point, the kink **624** at the side **614** is a high point, the kink **626** at the side **616** is a high point and the kink **628** at the side **618** is a low point. As used herein, "high point" refers to a point on a side of the reinforcement tie where the kink sharp twists or curves to have a high deviation. Also, as used herein, "low point" refers to a point on a side of the reinforcement tie where the kink sharp twists or curves to have a low deviation. For the purposes of description, the kinks **622**, **628** are referred to as lower kinks; and the kinks **624**, **626** are referred to as upper kinks.

Similarly, the reinforcement tie **700** as described in FIG. **9**B is a mirror image of the reinforcement tie **600** comprising hooks **752**, and kinks **722**, **724**, **726** and **728** at the midpoint of the four sides **712**, **714**, **716** and **718** respectively having deviation equal to W/2. Further, the reinforcement tie **700** comprises four corners **702**, **704**, **706** and **708**. For the purposes of description, the kinks **724**, **726** are referred to as lower kinks; and the kinks **722**, **728** are referred to as upper kinks.

Referring to FIG. **10**A, illustrates the pair of mid-side kinked rhombical reinforcement ties **600** and **700** of FIGS. **9**A and **9**B respectively forming a reinforcement tie unit **1000**A. For forming the reinforcement tie unit **1000**A, the reinforcement ties **600**, **700** are disposed at mirror inclinations to each other, such that, the reinforcement ties cross each other at diametrically opposite corners of the other reinforcement ties.

As illustrated in FIG. **10**A, the reinforcement tie **600** (first reinforcement tie) crosses from inside of the reinforcement tie **700** (second reinforcement tie) at the respective corners **606**, and **706**, and the reinforcement tie **700** crosses from inside of the reinforcement tie **600** at the respective corners **702**, and **602**, configuring two non-intersecting crossings. In a first crossing, the corner **606** of the reinforcement tie **600** is on the inside and the corner **706** of the reinforcement tie **700** is on outside. In this configuration the dual hook **752** of the reinforcement tie **700** engages the corner **606** of the reinforcement tie **600**. In a second crossing, the corner **702** of the reinforcement tie **700** is on the inside and the corner **602** of the rhombical reinforcement tie **600** is on outside. In this configuration, the dual hook **652** of the reinforcement tie **600** engages the corner **702** of the reinforcement tie **700**.

Further, as illustrated in FIG. **10**A, the reinforcement ties **600**, **700** are at mirror inclinations to each other such that a distance (spacing) between corners of the rhombical ties **600**, and **700** on the same structural bar is a pre-determined height H'. Specifically, as illustrated in FIG. **10**A, H' is the distance between corner **704** of the reinforcement tie **700** and corner **604** of the reinforcement tie **600**.

Now, referring to FIG. **10**B, illustrated are two pairs of mid-side kinked rhombical reinforcement ties of FIGS. **9**A, **9**B forming a multi-layered reinforcement tie unit **1000**B. The multi-layered reinforcement tie unit is only an unassembled representation (still not configured around the axially disposed structural bars) of the lateral reinforcement system **1090** of FIG. **10**C.

As illustrated in FIG. **10**B, mid-side kinked rhombical reinforcement tie **800** comprises hooks **852**, and kinks **822**, **824**, **826** and **828** on the midpoint having deviation equal to W/2 (not shown in FIG.) at the four sides **812**, **814**, **816** and **818** respectively of the individual reinforcement tie **800**. Further, the individual reinforcement tie **800** comprises four corners **802**, **804**, **806** and **808**. Similarly, mid-side kinked rhombical reinforcement tie **900** comprises hooks **952**, kinks **922**, **924**, **926** and **928** on the midpoint having deviation equal to W/2 (not shown in FIG.) at the four sides **912**, **914**, **916** and **918** respectively of the individual reinforcement tie **900** and comprises four corners **902**, **904**, **906** and **908**.

For forming the multi-layered reinforcement tie unit **1000**B, two-sub interwoven networks **1010** and **1020** are placed one above the other as shown in the FIG. **10**B. The two-sub interwoven networks **1010** and **1020** are placed one above the other in such a way such that the distance between the corner **804** of reinforcement tie **800** and corner **704** of tie **700** is approximately equal to H'/2. It will be evident to a person skilled in the art that the distance is not limited to H'/2 and can vary as per the configurational and reinforcement requirements.

Specifically, the side **916** of reinforcement tie **900** crosses the side **716** (not shown in the figure) of the reinforcement tie **700** at crossing point P**1**. The crossing at point Pb involves meeting of the upper kink **926** of reinforcement tie **900** and lower kink **726** (not shown in the figure) of reinforcement tie **700**. Further, the side **918** of reinforcement tie **900** crosses the side **718** (not shown in the figure) of the reinforcement tie **700** having a crossing at point P**2**. The crossing at point P**2** involves meeting of the lower kink **928** of reinforcement tie **900** and upper kink **728** (not shown in the figure) of reinforcement tie **700**. Again, the side **814** of reinforcement tie **800** crosses the side **614** (not shown in the figure) of the reinforcement tie **600** having a crossing at point P**3**. The crossing at point P**3** involves meeting of the lower kink **824** of reinforcement tie **800** and upper kink **624** (not shown in the figure) of the reinforcement tie **600**. Further, the side **812** of the reinforcement tie **800** crosses the side **612** (not shown in the figure) of the reinforcement tie **600** having a crossing at point P**4**. The crossing at point **4** involves meeting of the lower kink **622** (not shown in the figure) of the reinforcement tie **600** and upper kink **822** of the reinforcement tie **800**.

It will be apparent, however, to one skilled in the art that the multi-layered reinforcement tie unit **1000**B may contain one or more such sub interwoven networks placed one above the other in the similar pattern as described.

Now, referring to FIG. **10**C, illustrated is a lateral reinforcement system **1090** (assembled form) comprising a plurality of mid-side kinked rhombical reinforcement ties of FIGS. **9**A, **9**B forming a three-dimensional interwoven network around a plurality of axially disposed structural bars **1030**, **1040**, **1050** and **1060**. In the lateral reinforcement system **1090**, reinforcement ties **600**, **700**, **800**, **900**, **950** and **970** are disposed at an inclination to the axially disposed structural bars **1030**, **1040**, **1050** and **1060**. That is, the reinforcement ties **600**, **700**, **800**, **900**, **950** and **970** are disposed at an angle to the axially disposed structural bars **1030**, **1040**, **1050** and **1060** making it also inclined at an angle to a surface on which the axially disposed structural bars **1030**, **1040**, **1050** and **1060** are disposed. The reinforcement ties **950** and **970** are similar to the reinforcement ties **600**, **700**, **800**, **900** as described above.

In this configuration, the reinforcement ties in a pair of reinforcement ties cross each at diametrically opposite corners of the reinforcement ties at diametrically opposite structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from inside of the first mid-side reinforcement tie at the diametrically opposite structural bar.

For example, in a first crossing of the pair of reinforcement ties **600**, **700**, reinforcement tie **600** (first reinforcement tie) crosses from inside of the reinforcement tie **700** (second reinforcement tie) at the structural bar **1030**. In this crossing, the corner **606** of the reinforcement tie **100** is on the inside and the corner **706** of the reinforcement tie **700** is on outside. Further, in a second crossing, the reinforcement tie **700** (second reinforcement tie) crosses from inside of the reinforcement tie **600** (first reinforcement tie) at diametrically opposite structural bar **1060**. In this crossing, the corner **702** of the reinforcement tie **700** is on the inside and the corner **602** of the reinforcement tie **600** is on outside. Accordingly, the pair of reinforcement ties **600** and **700** is configured to form two non-intersecting crossings at the diametrically opposite structural bars **1030** and **1060**. Similarly, the pair of reinforcement ties **800** and **900** is configured to form two non-intersecting crossings at the diametrically opposite structural bars **1030** and **1060**. Also, the pair of reinforcement ties **950** and **970** is configured to form two non-intersecting crossings at the diametrically opposite structural bars **1030** and **1060**.

Additionally, the reinforcement ties cross each other at the kinks formed on corresponding reinforcement ties. Such crossing of reinforcement ties has been explained above with reference to FIG. **10**B at points P**1**, P**2** (not labeled), P**3**, and P**4**. It will be apparent from the illustration in FIG. **10**C, that due to the presence of more reinforcement ties in the lateral reinforcement system **1090**, there are additional crossing points (such as, P**17**, P**18**, P**19**, and other crossing points (not labeled)) at which the reinforcement ties cross each other at the kinks formed on corresponding reinforcement ties.

For forming the lateral reinforcement system **1090**, a plurality of mid-side kinked reinforcement tie units (such as the mid-side kinked reinforcement tie units **600**, **700**, **800**, **900**, **950** and **970**) are disposed on and the about the axially disposed structural bars **1030**, **1040**, **1050** and **1060**. The process comprises placing a first mid-side kinked reinforcement tie unit and then second mid-side kinked reinforcement tie unit on top of the first reinforcement tie unit, such that the kinks present in the lower half part of the second mid-side kinked reinforcement tie unit crosses the kinks present in the upper half part of the first mid-side kinked reinforcement tie unit and so on.

In this formation, the plurality of the mid-side kinked rhombical reinforcement ties **600**, **700**, **800**, **900**, **950** and **970** form a three-dimensional interwoven network around the axially disposed structural bars **1030**, **1040**, **1050** and **1060**. The three-dimension interwoven network is a collection of sub-interwoven networks **1010**, **1020**, **1070** formed by combining individual mid-side kinked reinforcement tie units.

Referring to FIGS. **11** and **12**, in another embodiment, illustrated is a pair of one-third side kinked rhombical reinforcement ties **1100** and **1200** respectively. As used herein, "one-third side kinked rhombical reinforcement tie" refers to a tie in shape of rhombus or diamond having kinks at the one-third point of the each of the four sides of the rhombical reinforcement tie.

The reinforcement tie **1100** as described in FIG. **11** is made of steel bar (or any other metallic/non-metallic bar) having a circular cross section of diameter W. Reinforcement tie **1100** comprises four corners **1102**, **1104**, **1106** and **1108**; and four sides **1112**, **1114**, **1116** and **1118**. Each side **1112**, **1114**, **1116** and **1118** has a length S. As shown in FIG. **11**, the reinforcement tie **1100** has a diagonal dimension M along a major axis and a diagonal dimension N along a minor axis. It will be evident to a person skilled in the art that the dimension nomenclature W, S, M and N are only for illustration and description purposes and the invention is not limited by such dimension nomenclature.

Further, the reinforcement tie **1100** comprises a dual hook member **1152** disposed at one of the corners of the reinforcement tie **1100**. As shown in FIG. **11**, the dual hook member **1152** is disposed at the corner **1102** of the reinforcement tie **1100**. The dual hook member **1152** provides for anchoring the one-third side kinked rhombical reinforcement tie **1100** to the load bearing element of the structural bars. Further, the dual hook member **1152** provides for engaging a corner of another reinforcement tie.

Further, the reinforcement tie **1100** comprises of kinks **1122** and **1124** on every one-third point of the side **1112**, thereby providing deviation equal to W/2. Accordingly, the side **1112** comprises kinks with a deviation dimension of half the cross-sectional diameter of the bar making the reinforcement tie **1100**. It will be evident to a person skilled in the art that the deviation dimension is not limited to W/2 and can vary as per the configurational and reinforcement requirements.

Similarly, the reinforcement tie **1100** comprises: kinks **1126** and **1128** at side **1114**, kinks **1130** and **1132** at the side **1116**; kinks **1130** and **1132** at the side **1116**; and kinks **1134** and **1136** at the side **1118**.

Specifically, the kinks **1122**, **1126**, **1132** and **1136** on the sides **1112**, **1114**, **1116** and **1118** respectively are the low points. The kinks **1124**, **1128**, **1130** and **1134** on the sides **1112**, **1114**, **1116** and **1118** respectively are the high points. As used herein, "high point" refers to a point on a side of the reinforcement tie where the kink sharp twists or curves to have a high deviation. Also, as used herein, "low point" refers to a point on a side of the reinforcement tie where the kink sharp twists or curves to have a low deviation.

Now, as illustrated in FIG. **12**, and similar to reinforcement tie **1100** of FIG. **11**, the reinforcement tie **1200** is made of steel bar (or any other metallic/non-metallic bar) having a circular cross section of diameter W. Reinforcement tie **1200** comprises four corners **1202**, **1204**, **1206** and **1208**; and four sides **1212**, **1214**, **1216** and **1128**. Each side **1212**, **1214**, **1216** and **1218** has a length S. As shown in FIG. **12**, the reinforcement tie **1200** has a diagonal dimension M along a major axis and a diagonal dimension N along a minor axis. It will be evident to a person skilled in the art that the dimension nomenclature W, S, M and N are only for illustration and description purposes and the invention is not limited by such dimension nomenclature.

Further, the reinforcement tie **1200** comprises a dual hook member **1252** disposed at one of the corners of the reinforcement tie **1200**. As shown in FIG. **11**, the dual hook member **1252** is disposed at the corner **1202** of the reinforcement tie **1200**. The dual hook member **1252** provides for anchoring the one-third side kinked rhombical reinforcement tie **1200** to the load bearing element of the structural bars. Further, the dual hook member **1252** provides for engaging a corner of another reinforcement tie.

The reinforcement tie **1200** is a mirror image of the reinforcement tie **1100**.

The reinforcement tie **1200** further comprises: kinks **1222** and **1224** at side **1212**; kinks **1226** and **1228** at side **1214**; kinks **1230** and **1232** at side **1216**; and kinks **1234** and **1236** at side **1218**. Also, as illustrated, the kinks provide a deviation equal to W/2. Specifically, the kinks **1222**, **1226**, **1232** and **1236** on the sides **1212**, **1214**, **1216** and **1218** respectively are the low points. The kinks **1224**, **1228**, **1230** and **1234** on the sides **1212**, **1214**, **1216** and **1218** respectively are the high points. For the purposes of description, the kinks **1222**, **1226**, **1232** and **1236** are referred to as lower kinks; and the kinks **1224**, **1228**, **1230** and **1234** are referred to as upper kinks.

Referring to FIG. **13**, illustrated is a pair of reinforcement ties **1100** and **1200** of FIGS. **11** and **12** respectively forming a reinforcement tie unit **1700**A. For forming the reinforcement tie unit **1700**A, the reinforcement ties **1100** and **1200** are disposed at mirror inclinations to each other, such that, the reinforcement ties cross each other at diametrically opposite corners of the other reinforcement ties.

As illustrated in FIG. **13**, the reinforcement tie **1100** (first tie) crosses from inside of the reinforcement tie **1200** (second tie) at the respective corners **1106** and **1206**, and the reinforcement tie **1200** crosses from inside of the reinforcement tie **1100** at the respective corners **1202** and **1102**, configuring two non-intersecting crossings. In a first crossing, the corner **1106** of the reinforcement tie **1100** is on the inside and the corner **1206** of the reinforcement tie **1200** is on outside. In this configuration, the dual hook **1252** of the reinforcement tie **1200** engages the corner **1106** of the reinforcement tie **1100**. In a second crossing, the corner **1202** of the reinforcement tie **1200** is on the inside and the corner **1102** of the reinforcement tie **1100** is on the outside. In this configuration, the dual hook **1152** of the reinforcement tie **1100** engages the corner **1202** of the reinforcement tie **1200**.

Further, as illustrated in FIG. **13**, the reinforcement ties **1100** and **1200** are at mirror inclinations to each other such that a distance (spacing) between corners of the rhombical ties **1100** and **1200** on the same structural bar is a predetermined height H'. Specifically, as illustrated in FIG. **13**, H' is the distance between corners **1204** and **1104** of the reinforcement ties **1100** and **1200** respectively. Also, as illustrated, in this configuration, the reinforcement ties **1100** and **1200** form a sub interwoven network **1710**.

Now, referring to FIG. **14**, illustrated are three pairs of one-third side kinked rhombical reinforcement ties of FIGS. **11**, **12** forming a multi-layered reinforcement tie unit **1700**B. Specifically, the multi-layered reinforcement tie unit **1700**B comprises reinforcement ties **1100**, **1200**, **1300**, **1400**, **1500** and **1600**. The one-third side kinked rhombical reinforcement ties **1300**, **1400**, **1500** and **1600** are similar to the reinforcement ties **1100** and **1200** as described with reference to FIGS. **13** and **14**. The numbering of the hooks kinks and corners are not shown in FIG. **14** for clarity of the illustration of the three-dimensional network. Each pair intersects a subsequent pair at one-third of the sides of the reinforcement ties. The multi-layered reinforcement tie unit **1700**B is only an unassembled representation (still not configured around the axially disposed structural bars) of the lateral reinforcement system of FIG. **14**.

Specifically, the multi-layered reinforcement tie unit **1700**B comprises of sub interwoven networks **1710**, **1720** and **1730** (similar to the sub interwoven networks **1710** as described above in reference to FIG. **13**). Specifically, the sub interwoven network **1720** is formed by reinforcement tie **1300** and the reinforcement tie **1400**. The sub interwoven network **1730** is formed by the reinforcement tie **1500** and the reinforcement tie **1600**.

For forming multi-layered reinforcement tie unit **1700**B, these three-sub interwoven networks **1710**, **1720** and **1730** are placed one above the other as shown in the FIG. **14** to form the multi-layered reinforcement tie unit **1700**B. The three-sub interwoven networks **1710**, **1720** and **1730** are placed one above the other in such a way such that the that the distance between the corners is approximately equal to H'/3. It will be evident to a person skilled in the art that the distance is not limited to H'/3 and can vary as per the configurational and reinforcement requirements.

Specifically, the sub interwoven network **1720** is placed above the sub interwoven network **1710** in such a way that the side **1414** of rhombical reinforcement tie **1400** crosses the side **1118** of the reinforcement tie **1100** at crossing point P**5**. The crossing at point P**5** involves meeting of the upper kink of the side **1414** of reinforcement tie **1400** and lower kink of the side **1118** of reinforcement tie **1100**. Further, the side **1412** of reinforcement tie **1400** crosses the side **1116** of the reinforcement tie **1100** at crossing point P**6**. The crossing at point P**6** involves meeting of the lower kink of the side **1412** of reinforcement tie **1400** and upper kink of the side **1116** of reinforcement tie **1100**.

The side **1312** of rhombical reinforcement tie **1300** crosses the side **1216** of the reinforcement tie **1200** at crossing point P**7**. The crossing at point P**7** involves meeting of the upper kink of the side **1216** of rhombical tie **1200** and lower kink of the side **1312** of reinforcement tie **1300**. Further, the side **1314** of reinforcement tie **1300** crosses the side **1218** of the reinforcement tie **1200** at crossing point P**8**. The crossing at point P**8** involves meeting of the lower kink of the side **1218** of reinforcement tie **1200** and upper kink of the side **1314** of reinforcement tie **1300**.

Similarly, the sub interwoven network **1730** is placed above the sub interwoven network **1720** in such a way that the side **1614** of reinforcement tie **1600** crosses the side **1318** of the reinforcement tie **1300** and side **1118** of the reinforcement tie **1100** at crossing point P**9** and P**10** respectively. The crossing at point P**9** involves meeting of the upper kink of the side **1614** of reinforcement tie **1600** and lower kink of the side **1318** of reinforcement tie **1300**. The crossing at point P**10** involves meeting of the lower kink of the side **1614** of the reinforcement tie **1600** and upper kink of the side **1118** of the reinforcement tie **1100**.

Further, the side **1612** of reinforcement tie **1600** crosses the side **1316** of the reinforcement tie **1300** and side **1116** of the reinforcement tie **1100** at crossing point P**11** and P**12** respectively. The crossing at point P**11** involves meeting of the lower kink of the side **1612** of rhombical tie **1600** and upper kink of the side **1316** of the reinforcement tie **1300**. The crossing at point P**12** involves meeting of the upper kink of the side **1612** of reinforcement tie **1600** and lower kink of the side **1116** of the reinforcement tie **1100**.

The side **1512** of reinforcement tie **1500** crosses the side **1416** of the reinforcement tie **1400** and the side **1216** of the reinforcement tie **1200** at crossing point P**13** and P**14** respectively. The crossing at point P**13** involves meeting of the lower kink of the side **1512** of reinforcement tie **1500** and upper kink of the side **1416** of reinforcement tie **1400**. The crossing at point P**14** involves meeting of the upper kink of the side **1512** of reinforcement tie **1500** and lower kink of the side **1216** of reinforcement tie **1200**.

Further, the side **1514** of reinforcement tie **1500** crosses the side **1418** of the reinforcement tie **1400** and side **1218** of the reinforcement tie **1200** at crossing point P**15** and P**16** respectively. The crossing at point P**15** involves meeting of the upper kink of the side **1514** of reinforcement tie **1500** and lower kink of the side **1418** of reinforcement tie **1400**. The crossing at point P**16** involves meeting of the lower kink of the side **1514** of the reinforcement tie **1500** and upper kink of the side **1218** of reinforcement tie **1200**.

It will be apparent, however, to one skilled in the art that the multi-layered reinforcement tie unit **1700**B may contain one or more such sub interwoven networks placed one above the other in the similar pattern as described.

Now, referring to FIG. **15**, illustrated is a lateral reinforcement system **1795** (assembled form) comprising a plurality comprising a plurality of one-third side kinked rhombical reinforcement ties of FIGS. **11**, **12** forming a three-dimensional interwoven network around a plurality of axially disposed structural bars **1760**, **1770**, **1780** and **1790**. In the lateral reinforcement system **1795**, reinforcement ties (not labeled) are disposed at an inclination to the axially disposed structural bars **1760**, **1770**, **1780** and **1790**. That is, the reinforcement ties (not labeled) are disposed at an angle to the axially disposed structural bars **1760**, **1770**, **1780** and **1790** making it also inclined at an angle to a surface on which the axially disposed structural bars **1760**, **1770**, **1780** and **1790** are disposed.

In this configuration, the reinforcement ties in a pair of reinforcement ties cross each at diametrically opposite corners of the reinforcement ties at diametrically opposite structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from inside of the first one-third side kinked rhombical reinforcement tie at the diametrically opposite structural bar.

Further, this configuration comprises placing a first one-third side kinked reinforcement tie unit and then second one-third side kinked reinforcement tie unit on top of the first reinforcement tie unit, such that the kinks present in the lower half part of the second one-third side kinked reinforcement tie unit crosses the kinks present in the upper half part of the first one-third side kinked reinforcement tie unit and thereafter placing the third one-third side kinked reinforcement tie unit, such that the kinks present in the lower half part of the third one-third side kinked reinforcement tie unit crosses the kinks present in the upper half part of the second one-third side kinked reinforcement tie and further crosses the kinks present upper half part of the first one-third side kinked reinforcement tie unit and so on.

In this formation, the plurality of the one-third side kinked rhombical reinforcement ties form a three-dimensional interwoven network around the axially disposed structural bars **1760**, **1770**, **1780** and **1790**. The three-dimension interwoven network is a collection of sub-interwoven networks formed by individual mid-side kinked reinforcement tie units. For example, as illustrated in FIG. **15**, a first sub-interwoven network **1710** is formed by the first one-third side kinked reinforcement tie unit, and a second sub-interwoven network **1720** is formed by the second one-third side kinked reinforcement tie unit.

It will be apparent, however, to one skilled in the art that the lateral reinforcement system **1700**B (assembled form) may contain one or more such sub interwoven networks placed one above the other in the similar pattern as described above to get the lateral reinforcement system **1700**B (assembled form). Such pattern is shown in FIG. **15** comprising sub-interwoven networks **1710**, **1720**, **1730**, **1740** and **1750**.

FIG. **16** illustrates an elliptical reinforcement tie **1800**, in accordance with another exemplary embodiment of the present invention. As used herein, “elliptical reinforcement tie” refers to a reinforcement tie in shape of an ellipse or oval (or any circular shape as per the shape of vertical member/horizontal member). The reinforcement tie **1800** is made of solid steel bar (or any other metallic/non-metallic bar) having a circular cross section of diameter W having major diameter D**1** and minor diameter D**2**. The diameter D**1** comprises two ends D**1**' and D**1**“and the diameter D**2** comprises two ends D**2**' and D**2**”. It will be evident to a person skilled in the art that the dimension nomenclature W is only for illustration and description purposes and the invention is not limited by such dimension nomenclature.

Further, the reinforcement tie **1800** comprises a dual hook member **1852** disposed at one of the end of the reinforcement tie **1800**. As shown in FIG. **16**, the dual hook member **1852** is disposed at the end D**2**" of the reinforcement tie **1800** as shown in FIG. **16**. The dual hook member **1852** provides for anchoring the reinforcement tie **1800** to the load bearing element of the structural bars. Further, the dual hook member **1852** provides for engaging an end of another elliptical reinforcement tie.

Referring to FIG. **17**A, illustrated is a pair of elliptical reinforcement ties of FIG. **16** forming a reinforcement tie unit **1900**A. In FIG. **17**A, the elliptical reinforcement ties are a first elliptical reinforcement tie **1800** and a second elliptical reinforcement tie **1900**. The second elliptical reinforcement tie **1900** is similar to the first elliptical reinforcement tie **1800** in shape and dimension, as described with reference to FIG. **16**. Specifically, the second elliptical reinforcement tie **1900** is made of solid steel bar (or any other metallic/non-metallic bar) having a circular cross section of diameter W having major diameter D**3** and minor diameter D**4**. The diameter D**3** comprises two ends D**3**' and D**3**" and the diameter D**4** comprises two ends D**4**' and D**4**". Further, the reinforcement tie **1900** comprises a dual hook member **1952** disposed at one of the end of the reinforcement tie **1900**. As shown in FIG. **17**A, the dual hook member **1952** is disposed at the end D**4**' of the elliptical tie **1900** as shown in FIG. **17**A.

For forming the reinforcement tie unit **1900**A, the reinforcement ties **1800**, **1900** are disposed at mirror inclinations to each other, such that, the reinforcement ties are rotated about minor diameters D**2**, D**4** and cross each other at diametrically opposite ends of the elliptical reinforcement ties, thereby configuring two non-intersecting crossings.

In a first crossing, the first elliptical reinforcement tie **1800** crosses from inside of the second elliptical reinforcement tie **1900**. Specifically, the end D**2**' of the first reinforcement tie **1800** is on the inside and the end D**4**' of the second reinforcement tie **1900** is on outside. In this configuration, the dual hook **1952** of the second reinforcement tie **1900** engages the end D**2**' of the first reinforcement tie **1800**.

In a second crossing, the second elliptical reinforcement tie **1900** crosses from inside of the first elliptical reinforcement tie **1800**. Specifically, the end D**4**" of the second reinforcement tie **1900** is on the inside and the end D**2**" of the first reinforcement tie **1800** is on outside. In this configuration, the dual hook **1852** of the first reinforcement tie **1800** engages the end D**4**" of the second reinforcement tie **1900**. Further, as illustrated in FIG. **17**A the inclination of reinforcement tie **1900** and reinforcement tie **1800** with reference to the base is H'. Also, as illustrated, in this configuration, the reinforcement ties **1800**, **1900** form a sub interwoven network **1910**.

Similarly, referring to FIG. **17**B, illustrated is a pair of elliptical reinforcement ties of FIG. **16** forming a reinforcement tie unit **1900**B. A sub interwoven network **1920** as illustrated in FIG. **17**B is the mirrored structure of the sub interwoven network **1910** as illustrated in FIG. **17**A. The sub interwoven network **1920** is formed by the elliptical reinforcement tie **2000** and elliptical reinforcement tie **2100**. Specifically, the sub interwoven network **1920** is rotated version of the sub interwoven network **1910**, which is rotated by 180 degree.

Now, referring to FIG. **18**, illustrated is a lateral reinforcement system **1900**C comprising a plurality of elliptical reinforcement ties of FIG. **16** forming a three-dimensional interwoven network around a plurality of axially disposed structural bars **2200**, **2300**, **2400** and **2500**. In the lateral reinforcement system **1900**C, the elliptical reinforcement ties **1800**, **1900**, **2000** and **2100** are disposed at an inclination to the axially disposed structural bars **2200**, **2300**, **2400** and **2500**. That is, the reinforcement ties **1800**, **1900**, **2000** and **2100** are disposed at an angle to the axially disposed structural bars **2200**, **2300**, **2400** and **2500** making it also inclined at an angle to a surface on which the axially disposed structural bars **2200**, **2300**, **2400** and **2500** are disposed.

In this configuration, the reinforcement ties in a pair of reinforcement ties cross each at diametrically opposite ends of the reinforcement ties at diametrically opposite structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from inside of the first reinforcement tie at the diametrically opposite structural bar. For example, in a first crossing, the reinforcement tie **1800** (first reinforcement tie) crosses from inside of the reinforcement tie **1900** (second reinforcement tie) at the structural bar **2300**. In this crossing, the end D**2**' of the reinforcement tie **1800** is on the inside and the end D**4**' of the reinforcement tie **1900** is on outside. Further, in a second crossing, the reinforcement tie **1900** (second reinforcement tie) crosses from inside of the reinforcement tie **1800** (first reinforcement tie) at diametrically opposite structural bar

2400. In this crossing, the end D**4**" of the second reinforcement tie **1900** is on the inside and the corner D**2**' of the first reinforcement tie **1800** is on outside. Accordingly, the pair of reinforcement ties **1800** and **1900** is configured to form two non-intersecting crossings at the diametrically opposite structural bars **2300** and **2400**.

The pair of elliptical reinforcement ties **2000** and **2100** is configured in a similar manner.

For forming the lateral reinforcement system **1900**C, a plurality of reinforcement tie units (such as the reinforcement tie unit **1900**A and **1900**B) are disposed on and the about the axially disposed structural bars **2200**, **2300**, **2400** and **2500**. The process comprises placing a first reinforcement tie unit and then another reinforcement tie unit on top of the first reinforcement tie unit, and so on. For example, the first reinforcement tie unit (herein referred to as reinforcement tie unit **1900**A) is formed by reinforcement ties **1800** and **1900** configured about each other and about the axially disposed structural bars **2200**, **2300**, **2400** and **2500** as explained above. Next, a second reinforcement tie unit is formed by reinforcement ties **2000** and **2100** and is placed over the first reinforcement tie unit **2000**.

In this formation, the plurality of elliptical reinforcement ties **1800**, **1900**, **2000** and **2100** form a three-dimensional interwoven network around the axially disposed structural bars **2200**, **2300**, **2400** and **2500**. The three-dimension interwoven network is a collection of sub-interwoven networks formed by individual reinforcement tie units. For example, as illustrated in FIG. **18**, a first sub-interwoven network **1910** is formed by the first reinforcement tie unit **1900**A, and a second sub-interwoven network **1920** is formed by the second reinforcement tie unit **1900**B. Although, in FIG. **18** herein, illustrated are only two reinforcement tie units forming two sub-interwoven networks, it will be evident to a person skilled in the art that the lateral reinforcement system can comprise more than two sub-interwoven networks as per the shape and size requirements of the structural bars and reinforcement requirement for a concrete structure.

Further, as illustrated in FIG. **18**, the reinforcement ties **1800**, **1900** are at mirror inclinations to each other such that a distance (spacing) between ends of the elliptical ties **1800**, **1900** on the same structural bar is a pre-determined height H". Specifically, as illustrated in FIG. **18**, H" is the distance between end D**1**' of the reinforcement tie **1800** and corner D**3**' of the reinforcement tie **1900** on the structural bar **2500**.

Now, referring to FIG. **19**A, illustrated are two pairs of elliptical reinforcement ties of FIG. **16** forming a multi-layered reinforcement tie unit **2600**A. The multi-layered reinforcement tie unit is only an unassembled representation (still not configured around the axially disposed structural bars) of the lateral reinforcement system **2600**B of FIG. **19**B.

For forming the multi-layered reinforcement tie unit **2600**A, two-sub interwoven networks **1910** and **1920** are placed one above the other as shown in the FIG. **19**A. The two-sub interwoven networks **1910** and **1920** are placed one above the other in such a way such that the distance between the end D**5**' of reinforcement tie **2100** and end D**3**' of tie **1900** is approximately equal to H'/2. It will be evident to a person skilled in the art that the distance is not limited to H'/2 and can vary as per the configurational and reinforcement requirements.

Specifically, the reinforcement tie **2100** crosses the reinforcement tie **1800** at crossing points P**17** and P**18** on the periphery at one third of the diameter along the major axis of the elliptical reinforcement tie **1800**. Further, the reinforcement tie **2000** crosses the reinforcement tie **1900** at crossing points P**19** and P**20** on the periphery at one third of the diameter along the major axis of the elliptical reinforcement tie **1900**.

It will be apparent, however, to one skilled in the art that the multi-layered reinforcement tie unit **2600**A may contain one or more such sub interwoven networks placed one above the other in the similar pattern as described.

Now, referring to FIG. **19**B, illustrated is a lateral reinforcement system **2600**B (assembled form) comprising a plurality of elliptical reinforcement ties of FIG. **16** forming a three-dimensional interwoven network around a plurality of axially disposed structural bars **3100**, **3200**, **3300** and **3400**. In the lateral reinforcement system **2600**B, reinforcement ties **1800**, **1900**, **2000**, **2100**, **2700**, **2800**, **2900** and **3000** are disposed at an inclination to the axially disposed structural bars **3100**, **3200**, **3300** and **3400**. That is, the reinforcement ties **1800**, **1900**, **2000**, **2100**, **2700**, **2800**, **2900** and **3000** are disposed at an angle to the axially disposed structural bars **3100**, **3200**, **3300** and **3400** making it also inclined at an angle to a surface on which the axially disposed structural bars **3100**, **3200**, **3300** and **3400** are disposed. The reinforcement ties **2700**, **2800**, **2900** and **3000** are similar to the reinforcement ties **1800**, **1900**, **2000** and **2100** as described above.

In this configuration, the reinforcement ties in a pair of reinforcement ties cross each other at minor diameters at diametrically opposite structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from outside of the first reinforcement tie at the diametrically opposite structural bar.

For example, in a first crossing of the pair of reinforcement ties **1800** and **1900**, reinforcement tie **1800** (first reinforcement tie) crosses from inside of the reinforcement tie **1900** (second reinforcement tie) at the structural bar **3300**. Further, in a second crossing, the reinforcement tie **1900** (second reinforcement tie) crosses from inside of the reinforcement tie **1800** (first reinforcement tie) at diametrically opposite structural bar **3200**. Accordingly, the pair of reinforcement ties **1800**, **1900** is configured to form two non-intersecting crossings at the diametrically opposite structural bars **3300** and **3200**. Similarly, the pair of reinforcement ties **2000**, **2100** is configured to form two non-intersecting crossings at the diametrically opposite structural bars **3300** and **3200**. Also, the pair of reinforcement ties **2700**, **2800**, **2900** and **3000** is configured to form two non-intersecting crossings at the diametrically opposite structural bars **3300** and **3200**.

For forming the lateral reinforcement system **2600**B, a plurality of elliptical reinforcement tie units (such as the elliptical reinforcement tie units **1800**, **1900**, **2000**, **2100**, **2700**, **2800**, **2900** and **3000**) are disposed on and the about the axially disposed structural bars **3100**, **3200**, **3300** and **3400**. The process comprises placing a first elliptical reinforcement tie unit and then second elliptical reinforcement tie unit on top of the first reinforcement tie unit, such that the crossing of the ties present in the lower half part of the second elliptical reinforcement tie unit crosses the ties present in the upper half part of the first elliptical reinforcement tie unit at the periphery at one third of the diameter along the major axis and so on.

In this formation, the plurality of the elliptical reinforcement ties **1800**, **1900**, **2000**, **2100**, **2700**, **2800**, **2900** and **3000** form a three-dimensional interwoven network around the axially disposed structural bars **3100**, **3200**, **3300** and

3400. The three-dimensional interwoven network is a collection of sub-interwoven networks 1910, 1920, 1930 and 1940 formed by combining individual elliptical reinforcement tie units.

Now, a further embodiment of the present invention is described herein with reference to FIGS. 20, 21, 22A and 22B.

Referring to FIG. 20, illustrated is an elliptical reinforcement tie similar to the reinforcement tie of FIG. 16 and rotated clockwise by a pre-determined angle. Referring to FIG. 21, illustrated is an elliptical reinforcement tie that is a mirror image of the reinforcement tie of FIG. 20 and rotated counter-clockwise by the pre-determined angle. Herein, the pre-determined angle is represented by θ.

Now, referring to FIG. 22A, illustrated are two pairs of elliptical reinforcement ties of FIGS. 20 and 21 forming a multi-layered reinforcement tie unit 3500A. Specifically, the first pair comprises of the elliptical reinforcement ties 1800 and 1900 as illustrated in FIG. 20 and FIG. 21 respectively and the second pair comprises of elliptical reinforcement ties 2000 and 2100. The elliptical reinforcement ties 2000 and 2100 is also similar to the elliptical ties as illustrated in FIG. 17B. In this configuration, the elliptical reinforcement ties 2000 and 2100 are rotated clockwise and anticlockwise respectively by pre-determined angle θ.

The multi-layered reinforcement tie unit 3500A is only an unassembled representation (still not configured around the axially disposed structural bars) of the lateral reinforcement system 3500B of FIG. 22B.

For forming the multi-layered reinforcement tie unit 3500A, two-sub interwoven networks 3510 and 3520 are placed one above the other as shown in the FIG. 22A.

Specifically, the reinforcement tie 2000 crosses the reinforcement tie 2100 at crossing points P25 and P26 and further crosses the reinforcement tie 1800 at crossing points P23 and P24. The crossing points are on the periphery at one third of the diameter along the major axis of the elliptical reinforcement ties. Specifically, at crossing point P25, the reinforcement tie 2000 crosses from outside the reinforcement tie 2100 and at crossing point P26 the reinforcement tie 2000 crosses from inside the reinforcement tie 2100. Further, at crossing point P23, the reinforcement tie 2000 crosses from inside the reinforcement tie 1800; and at crossing point P24, the reinforcement tie 2000 crosses from outside the reinforcement tie 1800. Similarly, the reinforcement tie 1800 crosses the reinforcement tie 1900 at the crossing points P21 and P22. At the crossing point P21, the reinforcement tie 1800 crosses from inside the reinforcement tie 1900 and at the crossing point P22 the reinforcement tie 1800 crosses from outside the reinforcement tie 1900.

It will be apparent, however, to one skilled in the art that the multi-layered reinforcement tie unit 3500A may contain one or more such sub interwoven networks placed one above the other in the similar pattern as described.

Now, referring to FIG. 22B, illustrated is a lateral reinforcement system 3500B (assembled form) comprising a plurality of elliptical reinforcement ties of FIG. 20 and FIG. 21 forming a three-dimensional interwoven network around a plurality of axially disposed structural bars 3600, 3700, 3800 and 3900. In the lateral reinforcement system 3500B, reinforcement ties 1800, 1900, 2000, 2100, 2700 and 2800 are disposed at an inclination to the axially disposed structural bars 3600, 3700, 3800 and 3900. That is, the reinforcement ties 1800, 1900, 2000, 2100, 2700 and 2800 are disposed at an angle to the axially disposed structural bars 3600, 3700, 3800 and 3900 making it also inclined at an angle to a surface on which the axially disposed structural bars 3600, 3700, 3800 and 3900 are disposed. The reinforcement ties 2700 and 2800 are similar to the reinforcement ties 1800 and 1900 as described above.

In this configuration, the reinforcement ties in a pair of reinforcement ties cross each other at diametrically opposite structural bars, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties at one structural bar, and the second reinforcement tie crosses from outside of the first reinforcement tie at the diametrically opposite structural bar.

For forming the lateral reinforcement system 3500B, a plurality of elliptical reinforcement tie units (such as the elliptical reinforcement tie units 1800, 1900, 2000, 2100, 2700 and 2800) are disposed on and the about the axially disposed structural bars 3600, 3700, 3800 and 3900. The process comprises placing a first elliptical reinforcement tie unit and then second elliptical reinforcement tie unit on top of the first reinforcement tie unit, such that the crossing of the ties present in the lower half part of the second elliptical reinforcement tie unit crosses the ties present in the upper half part of the first elliptical reinforcement tie unit at the periphery at one third of the diameter along the major axis and so on.

In this formation, the plurality of the elliptical reinforcement ties 1800, 1900, 2000, 2100, 2700 and 2800 form a three-dimensional interwoven network around the axially disposed structural bars 3600, 3700, 3800 and 3900. The three-dimensional interwoven network is a collection of sub-interwoven networks 3510, 3520 and 3530 formed by combining individual elliptical reinforcement tie units.

Also, the present invention provides a method for lateral reinforcement using the lateral reinforcement system of the present invention comprising the plurality of the reinforcement ties of the present invention.

Also, techniques, devices, subsystems and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present technology.

It should be noted that reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages should be or are in any single embodiment. Rather, language referring to the features and advantages may be understood to mean that a specific feature, advantage, or characteristic described in connection with an embodiment may be included in at least one embodiment of the present technology. Thus, discussions of the features and advantages, and similar language, throughout this specification may, but do not necessarily, refer to the same embodiment.

The invention claimed is:

1. A lateral reinforcement system for a concrete structure having axially disposed structural bars, the lateral reinforcement system comprising:

a plurality of reinforcement ties disposed at a non-orthogonal inclination to the axially disposed structural bars; wherein each of said plurality of reinforcement ties includes a dual hook member

wherein a pair of reinforcement ties of the plurality of reinforcement ties

cross each other at the dual hook member of the reinforcement ties, such that, a first reinforcement tie of the pair of reinforcement ties crosses from inside of a second reinforcement tie of the pair of reinforcement ties on one face, and the second reinforcement tie crosses from inside of the first reinforcement tie at an opposite face, and

wherein the plurality of reinforcement ties form a three-dimensional interwoven network around the axially disposed structural bars.

2. The lateral reinforcement system of claim **1**, wherein the dual hook member are capable of

anchoring the reinforcement tie to the structural bars, and

engaging a corner of another reinforcement tie.

3. The lateral reinforcement system of claim **2**, wherein the first tie engages the second tie from the outside when crossing the second tie; and the second tie engages the first tie from the outside when crossing the first tie at the opposite corner.

4. The lateral reinforcement system of claim **1**, wherein the ties are rhombical shaped reinforcement ties.

5. The lateral reinforcement system of claim **4**, wherein the ties are mid-side kinked rhombical shaped reinforcement ties, each tie comprising a kink at the midpoint of each rhombical side of the rhombical shaped reinforcement tie.

6. The lateral reinforcement system of claim **5**, wherein the pair of rhombical shaped reinforcement ties are placed at opposing inclination so that they cross each other at the kink of a corresponding rhombical side.

7. The lateral reinforcement system of claim **4**, wherein the rhombical shaped reinforcement ties are one-third side kinked rhomboidal shaped, each tie comprising a kink at every one-third length of each rhombical side of a tie.

8. The lateral reinforcement system of claim **7**, wherein the rhombical shaped reinforcement ties cross each other at the kink of a corresponding rhombical shaped reinforcement tie.

9. The lateral reinforcement system of claim **1**, wherein the ties are elliptical shaped reinforcement ties.

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